# OVERHAUL MANUAL

## *Cyclone 9 GC*

# OVERHAUL MANUAL

# WRIGHT AIRCRAFT ENGINES
# CYCLONE 9 GC

THIRD EDITION

(Part No. 114323-N3)

WRIGHT AERONAUTICAL CORPORATION
(A DIVISION OF CURTISS-WRIGHT CORPORATION)
PATERSON, NEW JERSEY, U.S.A.
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Paterson, New Jersey, U. S. A.

# WRIGHT GUARANTEE

WE warrant each new engine manufactured by us to be free from defects in material and workmanship under normal use and service and proper installation; our obligation under this warranty being limited to making good at our factory any part or parts thereof which shall within ninety days after delivery of such engine to the original purchaser be returned to us with transportation charges prepaid and which our examination shall disclose to our satisfaction to have been defective; this warranty being expressed in lieu of all warranties expressed or implied and of all other obligations or liabilities on our part. We neither assume nor authorize any other person to assume for us any other liability in connection with the sale of our engine.

This warranty does not cover any labor charges for the replacement of parts, adjustments, repairs, or other work done on Wright engines.

This warranty shall not apply to any engine which shall have been repaired or altered outside of our factory in any way so as, in our judgment, to affect its stability, or which has been subject to misuse, negligence, or accident, or which shall have been operated at a speed exceeding the factory rated speed.

This warranty shall not apply to any engine which shall have been operated with other than the specified fuel and oil.

We reserve the right to revise, change, or modify the whole or any part of the construction of Wright engines without incurring any obligation to make the changes on engines previously sold.

We make no warranty whatever in respect to ignition, starting devices, generators, carburetors, or other trade accessories, inasmuch as these are usually warranted separately by their respective manufacturers.

**WRIGHT AERONAUTICAL CORPORATION**
**A Division of Curtiss-Wright Corporation**
**Paterson, New Jersey, U. S. A.**

# PREFACE

THIS Overhaul Manual is recommended for the use of professional mechanics and operators, that they may avail themselves of the knowledge acquired by the Service Division of the Wright Aeronautical Corporation during the past twenty years of overhauling Wright aircraft engines.

This is the third edition of the Cyclone 9GC Overhaul Manual and it supersedes the second edition of this publication. The practices described in this manual, when followed in connection with the overhaul of Cyclone 9GC Engines, will insure the utmost in engine performance and shop efficiency.

No reference is made to engine part numbers nor are the tools mentioned throughout the text described to any extent other than is necessary to understand their use. Parts and Tool Catalogs are published separately. It is recommended that those connected with the operation or maintenance of Wright engines acquaint themselves with these two catalogs.

This manual has been confined strictly to overhaul procedure and directly related subjects; all general information such as instructions for starting, operation, and periodic inspection have been incorporated in the Instruction Book furnished with each engine.

Instructions covering the maintenance and overhaul of engine accessories, such as carburetors and magnetos, have been omitted, inasmuch as these parts are not manufactured by the Wright Aeronautical Corporation. Complete information for the repair of the various accessories may be obtained from their respective manufacturers.

Should any additional information be desired concerning the overhaul of Wright engines, the Service Division of the Wright Aeronautical Corporation will be pleased to handle all requests for such information.

For the benefit of its customers, the Wright Aeronautical Corporation issues separate publications which will be supplied to owners of Wright engines, at no charge, upon request to the factory. For non-owners, a price list of publications is available and will be supplied upon request. Included are:

**SERVICE BULLETINS** — These are issued for those actively engaged in servicing Wright engines to supplement the instructions contained in Overhaul Manuals and Instruction Books as additional information and improvements become available or when changes in certain operating or servicing procedures are recommended.

**TOOL CATALOG** — (Part No. 852515 for C9GC.) This catalog lists and describes the tools for overhauling the Cyclone 9GC engine. A separate Parts and Tools Price List is available and will be supplied upon request.

**LIMITS AND LUBRICATION CHARTS** — (20 in. x 20 in.) These charts, which are to be used in conjunction with current editions of the Table of Limits, contain reference numbers indicating the location of fits and clearances. They also indicate the engine lubrication system in colors.

**PARTS REFERENCE DIAGRAMS** — (Part No. 853589 for C9GC.) This is a set of 22 charts (30 in. x 40 in.) which show major engine assemblies in exploded form with each part or the chart having the part named.

**CRUISING POWER CALCULATORS** — These calculators furnish a quick means of computing the engine horsepower output for any normal combination of rpm, manifold pressure, and altitude.

The Wright Aeronautical Corporation welcomes suggestions for improving the engine, its equipment, or its servicing, and invites constructive criticism of this Overhaul Manual. Such suggestions are greatly appreciated and will receive careful consideration. It is earnestly requested that all service and overhaul problems be submitted to the Service Division.

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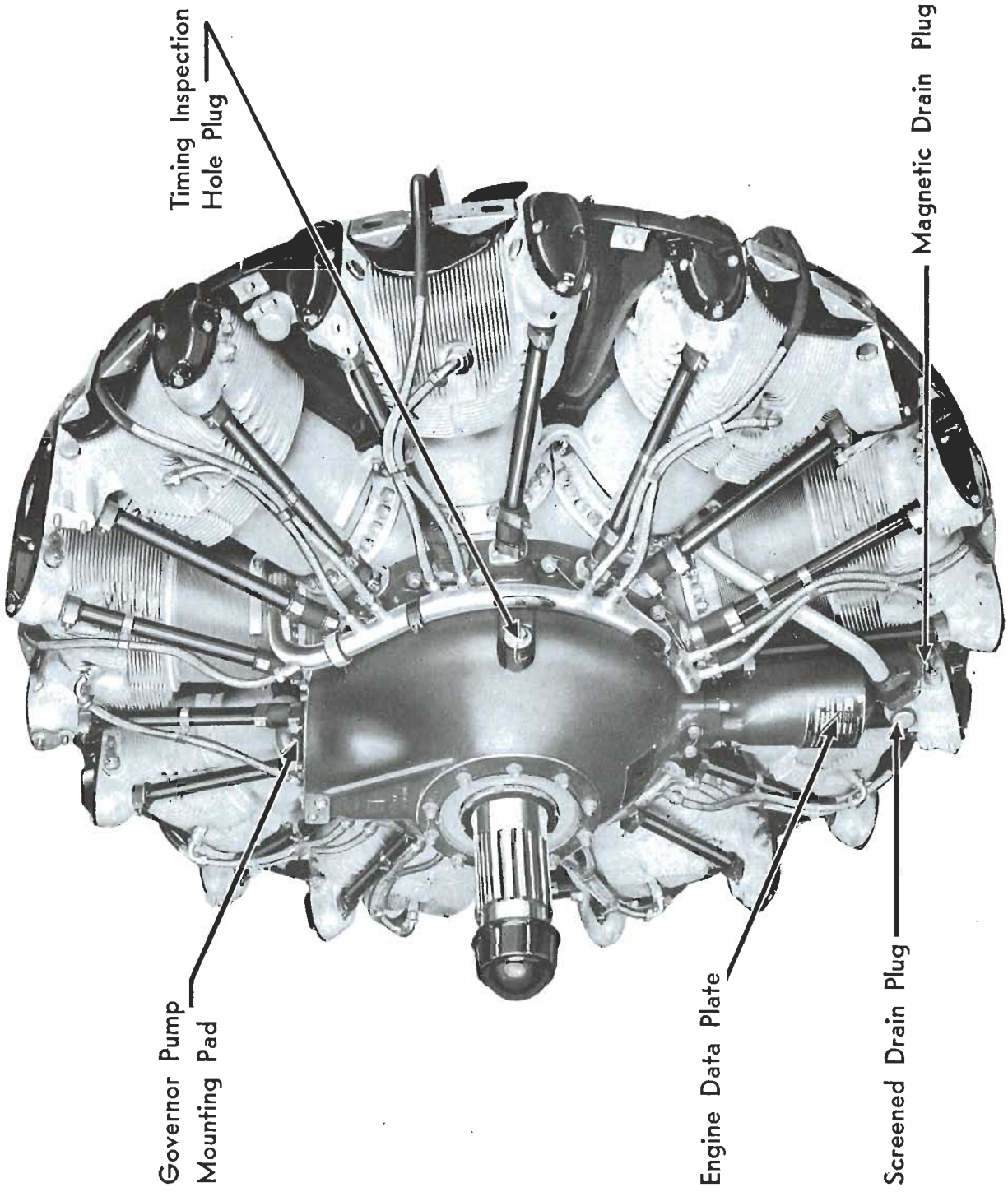



Fig. 1. Three Quarter Left Front View of Cyclone 9GC

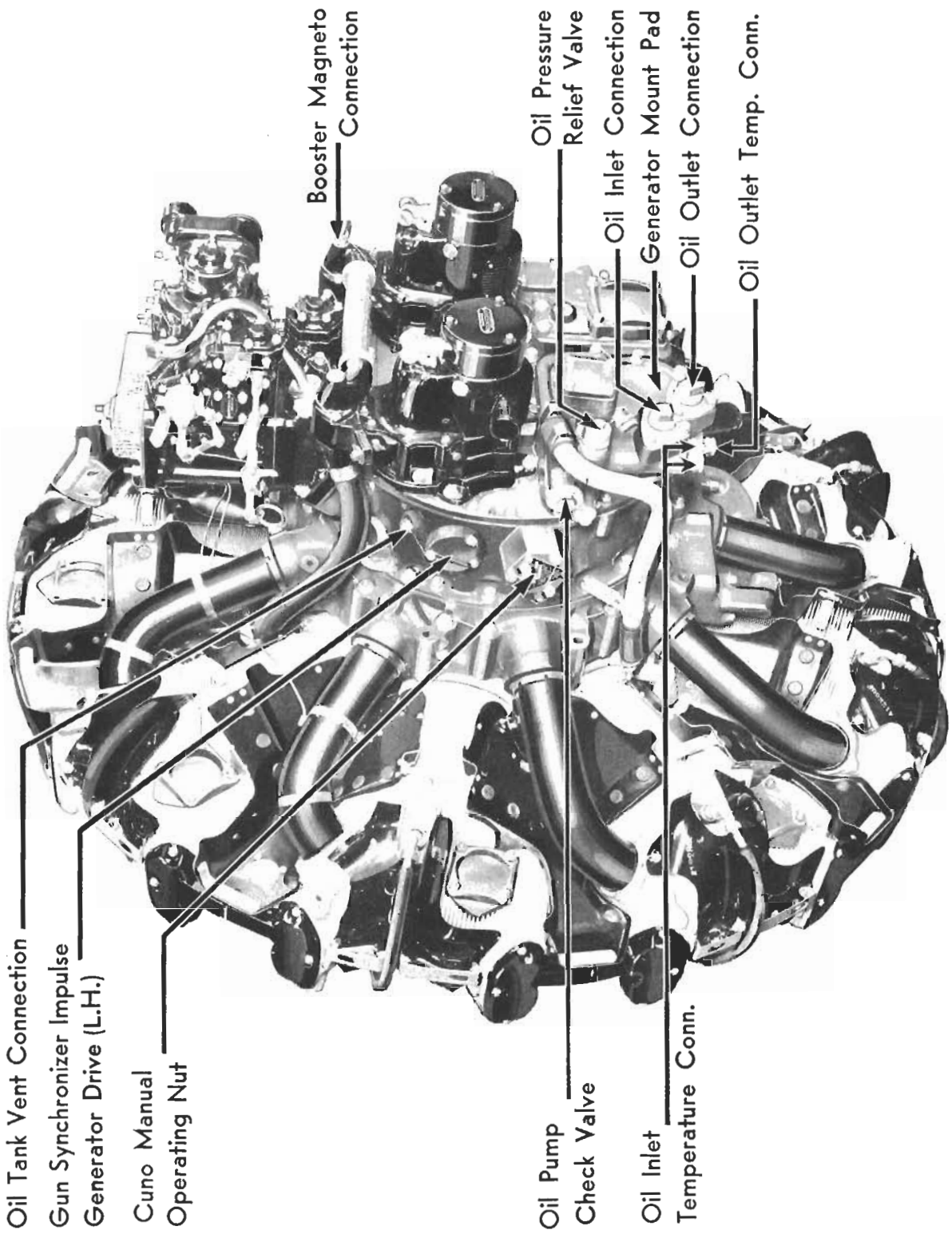



**Fig. 2. Three Quarter Left Rear View of Cyclone 9GC**

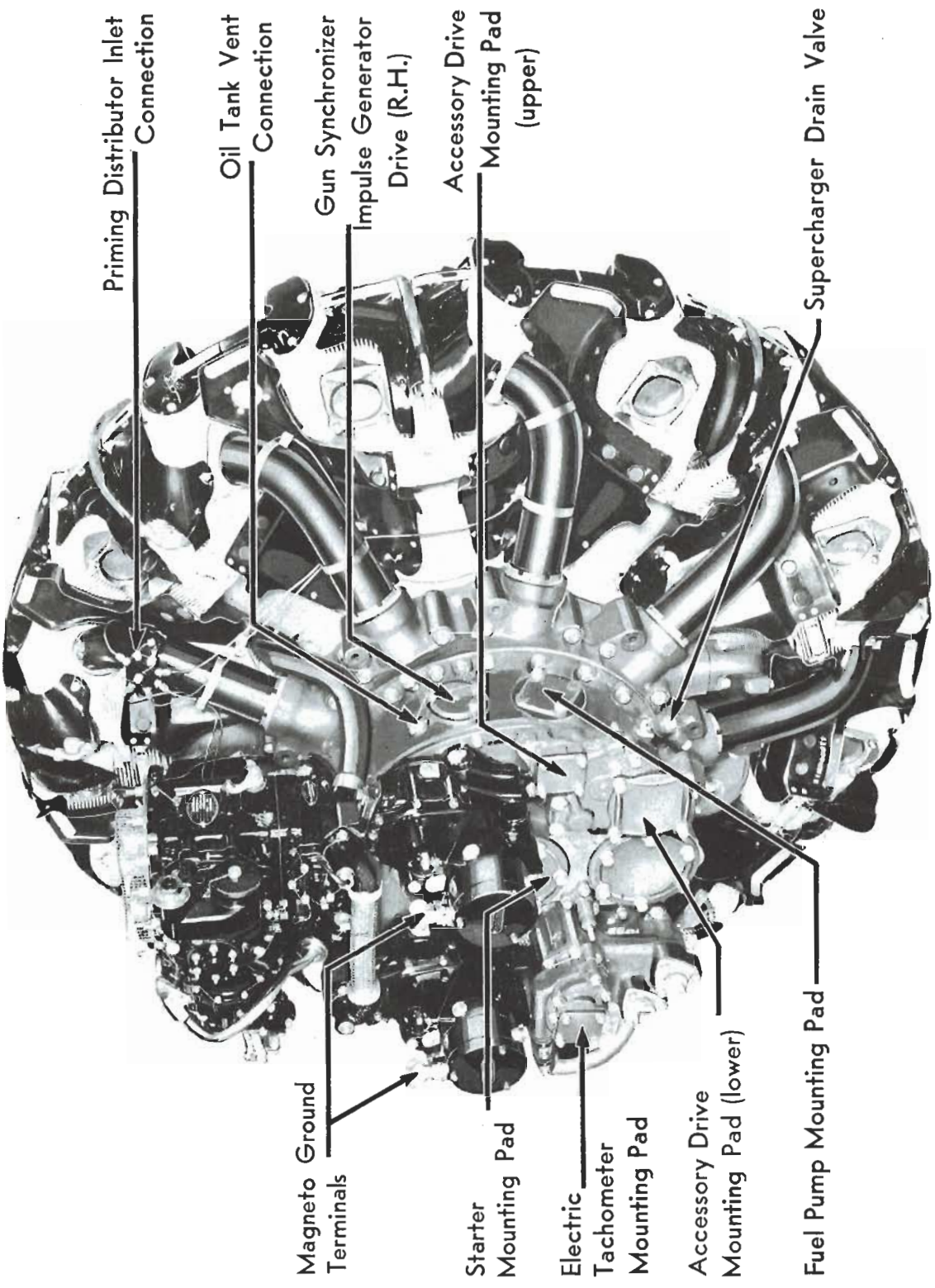

Priming Distributor Inlet Connection
Oil Tank Vent Connection
Gun Synchronizer Impulse Generator Drive (R.H.)
Accessory Drive Mounting Pad (upper)
Supercharger Drain Valve
Magneto Ground Terminals
Starter Mounting Pad
Electric Tachometer Mounting Pad
Accessory Drive Mounting Pad (lower)
Fuel Pump Mounting Pad

**Fig. 3. Three Quarter Right Rear View of Cyclone 9GC**

# FOREWORD

**METRIC DIMENSIONS**

All measurements given throughout the various chapters of this Manual are English units, followed by a metric unit in parentheses. The metric unit is a direct conversion of the English unit, and is given for the convenience of those operators who prefer to work in metric units.

**TOP OVERHAUL**

Top overhaul consists of removing cylinder assemblies for the purpose of cleaning carbon from the pistons and cylinder heads, repair of the valve operating gear and replacement of the valve guides and piston rings if necessary.

The experience of the past few years indicates that valves and pistons do not require more frequent attention than do the other major parts of the engine.

In view of these facts the Wright Aeronautical Corporation finds that periodic top overhauling of the Cyclone engine is unnecessary. We therefore do not recommend continuance of this practice on engines which operate under normal conditions. Systematic checking of the engine at stated periods, as outlined in the respective Instruction Books, is necesssary and must not be confused with this recommendation.

A condition might arise which would require the removal of one or more cylinders, due to loss of compression. Should this condition exist, the removal of the offending cylinder or cylinders is recommended.

**INSTALLATION OF UNAPPROVED PARTS IN WRIGHT AIRCRAFT ENGINES**

From time to time information reaches the Wright Aeronautical Corporation that engine parts which are not genuine Wright parts have been installed in Wright engines. In most cases this practice has been brought to light by the failure of the parts in question, subsequent examination proving them to be defective both in material and workmanship. The use of parts which have not been procured from the Wright Aeronautical Corporation or through its authorized agents constitutes a misuse of the engine and voids the engine guarantee.

Realizing that if such a practice were to become widespread it would seriously affect public safety, the Civil Aeronautics Authority includes in their Civil Air Regulations Bulletin No. 13, as effective August 1, 1941, the following clause:

> Section 13.2150, Engine Adjustments and Parts Replacements "(d) Parts used to replace other parts . . . shall satisfactorily meet the 150-hour endurance test; provided, that the administrator may accept other substantially equivalent proof of such parts."

To obtain this approval it is necessary for the manufacturer of any engine part to equip an engine of a specified type with said part and subject it to the same tests required for granting of an Engine Approved Type Certificate. In addition to this, the manufacturer must submit descriptive data of all parts, and the factory of the manufacturer must be inspected by the Board.

The airworthiness of aircraft engines depends upon adherence to the above and other related Civil Aeronautics Authority Regulations. These facts are brought to the attention of licensed mechanics, since any mechanic who has made or supervised the installation of parts in an engine, not in compliance with Civil Air Regulations, is liable to suspension or revocation of his license.

**SPECIAL NOTES**

**INSPECTION OF REPLACEMENT PARTS** Certain assemblies and detail parts supplied for replacements on Wright engines require line reaming or similar operations at assembly on the engine. Whenever possible, special fixtures are used to perform these operations during manufacture to eliminate this machining at assembly. In either case, wax or semisolid grease is often used to fill out passages where metal chips from the machining operations might otherwise collect. If the wax or grease used for this purpose is not completely re-

moved before the engine is assembled, obstruction of the lubrication to certain bearings or other parts may exist. Failures or serious damage to the engine may result from such obstruction.

It is therefore recommended that whenever spart parts are to be assembled in an engine, an inspection be made to insure that all oil passages are clear. Extreme care is taken in the manufacture of spare parts to insure that oil passages which have been filled prior to machining operations are thoroughly cleaned out before the parts are shipped. As an additional precaution, however, it is recommended that operators inspect these parts for clear passages before assembly.

CHAPTER I

# GENERAL DESCRIPTION

THE WRIGHT CYCLONE 9GC engine (formerly designated as the GR-1820-G200 model) is of the single-row, nine-cylinder, air-cooled, static radial type, operating on the conventional four-stroke cycle. The cylinder bore is 6.125 inches (155.6 mm), and the piston stroke is 6.875 inches (174.6 mm), giving a total piston displacement of 1823 cubic inches (29.88 liters). Cylinders are fired in the following order: 1, 3, 5, 7, 9, 2, 4, 6, 8, clockwise, viewed from the rear of the engine.

Throughout this book the propeller end of the engine will be referred to as the "Front" of the engine, and the antipropeller end will be referred to as the "Rear" of the engine.

The terms "Right" and "Left" refer to the viewpoint of an observer facing the antipropeller or rear end of the engine. Rotation of the propeller is clockwise as viewed from this position. The cylinders are numbered in a clockwise direction beginning with the top cylinder as number one. The term "Horizontal Position" will be used to designate the position of the engine in level flight.

**CYLINDERS** The cylinders are built up by shrinking threaded cast-aluminum-alloy heads on forged steel barrels. Cooling fins are cast in the cylinder head and machined in the barrel. The exhaust port boss faces toward the rear of the engine and is provided with four studs for securing the exhaust stacks. The intake port boss is at the rear of the cylinder head and faces toward the right and slightly downward, toward the center of the engine, in order to allow for smooth uninterrupted flow of mixture to the cylinder. Rubber packing is used between the intake pipe flange and cylinder head. A boss, located just forward of the intake pipe flange on each cylinder intake port, is drilled and tapped to receive either a priming-line fitting or a plug. The valves are inclined to the center line of the cylinder at an angle, permitting a hemispherical combustion chamber. Bronze valve guides and steel valve seats are shrunk into the cylinder head. Bronze spark plug inserts are screwed and pinned in the front and rear of each cylinder head. The inserts are just above the main horizontal cooling fins of the head and located symmetrically and at 90 deg. to each other. They are surrounded with deep vertical cooling fins.

The intake and exhaust rocker boxes are provided with four studs for securing the rocker box covers. The rocker arm bolt bosses are equipped with bronze bushings. Bosses equipped with studs are cast at the front and rear of the intake rocker boxes for securing the engine cowling. Push rod housing connections are screwed into the forward end of the rocker boxes forming oil-tight seals. The rocker box covers are provided with integrally cast extensions which form a complete circle around the engine when assembled. Intercylinder deflectors are attached to these extensions with plates, making a satisfactory air seal without the use of leather seals.

The cylinder barrel, with integral cooling fins, attaching flange, and threads to secure the head, is machined from a steel forging. The surface of the cylinder bore is nitrided to provide increased life. Twenty holes are provided in the cylinder attaching flange for attachment of the cylinder assembly to the crankcase by cap screws. Spherical seat washers are used under the cap screw heads. See figure 4.

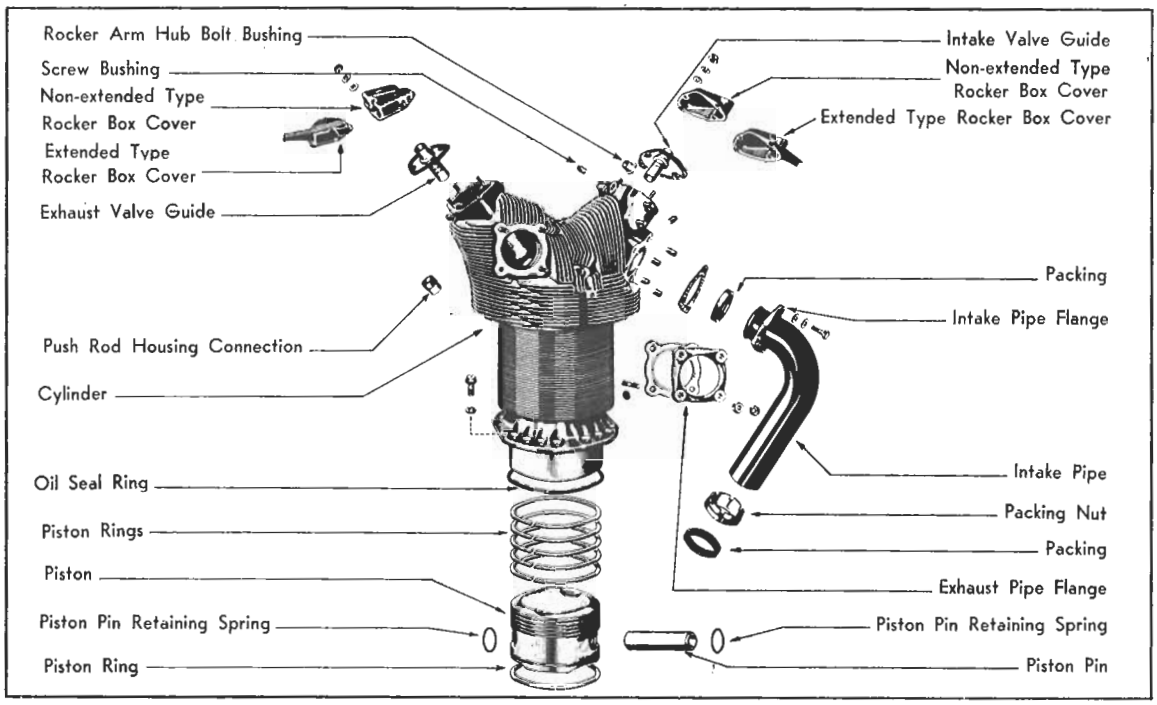



**Fig. 4. Cylinder, Intake Pipe, Piston, and Piston Rings.**

**AIR DEFLECTORS** Pressure type, close seating, cylinder-head and barrel air deflectors of sheet aluminum-alloy are used to direct the flow of air through the cooling fins with maximum efficiency. Because of a variance in the construction of the deflectors used in different locations on the engine, care should be taken to mark each deflector removed from the engine to insure correct reinstallation. See figure 5.

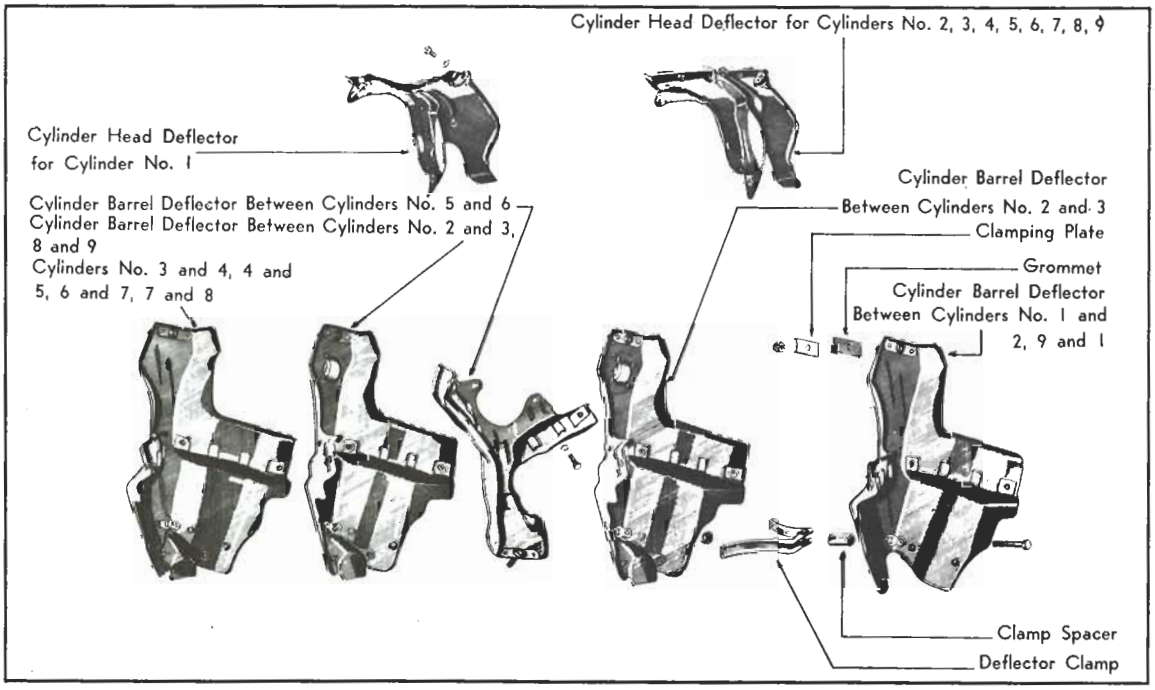

Cylinder Head Deflector for Cylinders No. 2, 3, 4, 5, 6, 7, 8, 9
Cylinder Head Deflector
for Cylinder No. 1
Cylinder Barrel Deflector Between Cylinders No. 5 and 6
Cylinder Barrel Deflector Between Cylinders No. 2 and 3, 8 and 9
Cylinders No. 3 and 4, 4 and 5, 6 and 7, 7 and 8
Cylinder Barrel Deflector
Between Cylinders No. 2 and 3
Clamping Plate
Grommet
Cylinder Barrel Deflector
Between Cylinders No. 1 and 2, 9 and 1
Clamp Spacer
Deflector Clamp

**Fig. 5. Air Deflectors.**

**CRANKCASE** The crankcase is built up of six principal sections of heat-treated metal alloy. The front section, a magnesium-alloy casting, contains the main thrust ball bearing and furnishes support for the cam followers, or tappets, which actuate the valves through push rods and rocker arms. The stationary reduction gear and reduction-gear pinion guard ring are bolted at the forward end inside the front section. The governor drive assembly consists of a single vertical shaft mounted in the front section. The bevel gear drive is taken from the intermediate governor drive gear mounted on the cam intermediate drive gear.

A steel thrust nut oil seal ring flange and aluminum spacer are bolted to the front face of the front section. The thrust nut oil seal rings bear on the inside circumference of this flange. The forward end of the oil sump is attached to the lower part of the front section. The front section contains oil passages for the hydro-high and hydro-low pressure oil, used in conjunction with a hydraulically-operated propeller. The inner rear parting surface of the front section includes a channel, sealed by a rubber packing ring, which carries oil to the tappet assemblies. See figure 6.

The crankcase front section is attached to the crankcase front main section by cap screws.

The crankcase front and rear main sections are machined from steel forgings. They are parted on the cylinder center line and are attached by short bolts through internal lugs. A boss in the center of the front half is provided to receive the cam. A bronze cam bearing is shrunk on the outside circumference of this boss. See figure 7.

The supercharger front housing is machined from a magnesium-alloy casting having nine mounting lugs for supporting the engine and nine tapped bosses for intake pipe connections. The diaphragm, or web, of the supercharger front housing forms the forward wall of the diffuser section and distribution chamber. The impeller shaft front oil sleeve support is mounted on the diaphragm and held

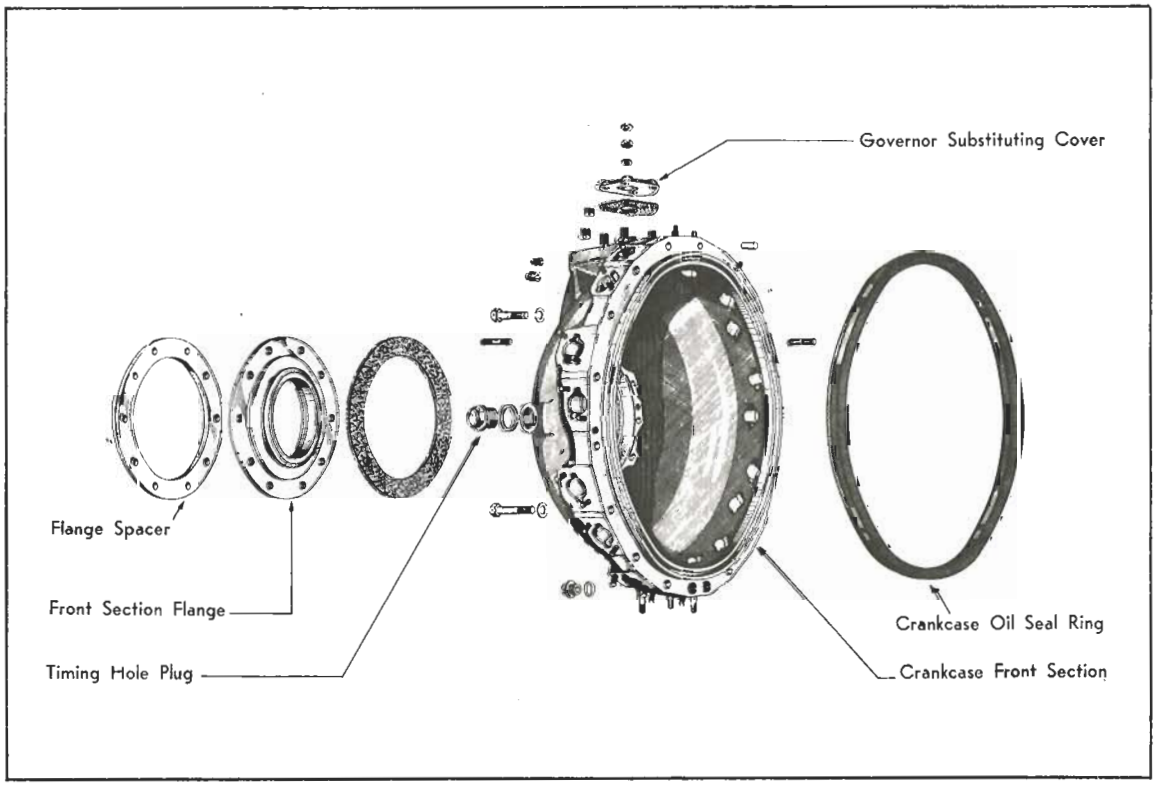



**Fig. 6. Crankcase Front Section.**

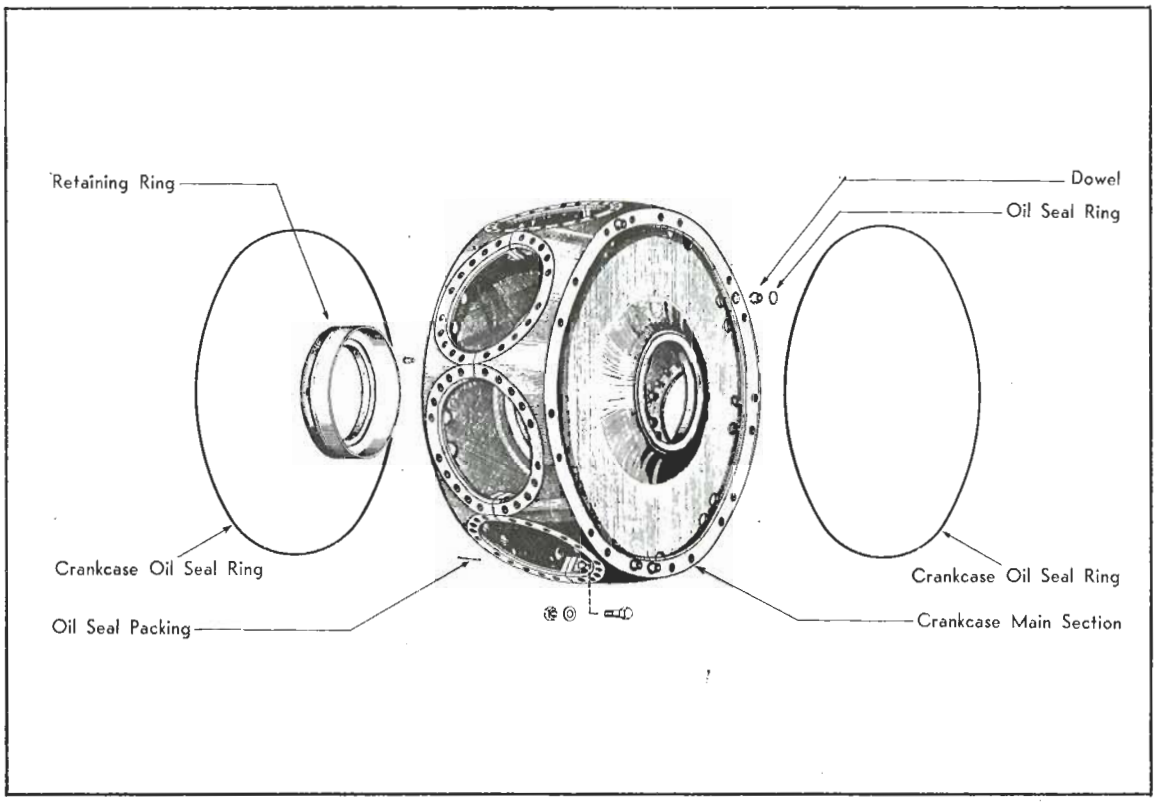



**Fig. 7. Crankcase Main Section.**

in place by a steel retainer ring which is secured to the diaphragm by eight short screws. The front wall is cored around the rim to form a breather passage. Bosses with tapped holes are provided at the base of the intake pipe connections to cylinders No. 2, 8, and 9 for priming-line and manifold pressure connections. Five plugs are permanently installed in the front wall of the supercharger front section for manufacturing purposes and a crankcase breather relief valve is screwed into the remaining hole. Cored holes in the bottom of the housing form drainage and suction passages to the oil sump which is attached to the bottom of the crankcase front section and the supercharger front housing. The supercharger front housing is attached to the crankcase rear main section by means of eighteen cap screws. See figure 8.

The magnesium-alloy supercharger rear housing contains the induction passage to the impeller entrance and houses all accessory drive gears. The vane-type diffuser plate is attached to the forward end of the induction passage, where it shrouds the impeller. The supercharger rear housing, which is attached to the supercharger front housing by studs, forms the rear wall of the diffuser chamber. An automatic oil filter is attached to the left side of the rear housing. Two gun-synchronizer impulse generator drives or substituting covers and a fuel pump are also mounted on the sides of this section. The impeller shaft rear oil seal assembly is supported in the steel sleeve which is shrunk in at the center of the diaphragm which forms the rear wall of the induction passage. Vent passages in the supercharger rear housing line up with similar passages in the supercharger front housing to equalize the rear section and crankcase pressures. Two holes equipped with combustion-type cabin heater inlet connections are drilled in opposite sides of the supercharger rear housing adjacent to the forward flange. Provision has been made for the installation of a one-half inch, pipe tap, heater exhaust connection in the left rear face of the carburetor adapter. Cored drainage and suction passages communicate with similar passages in the supercharger front housing. See figure 8.

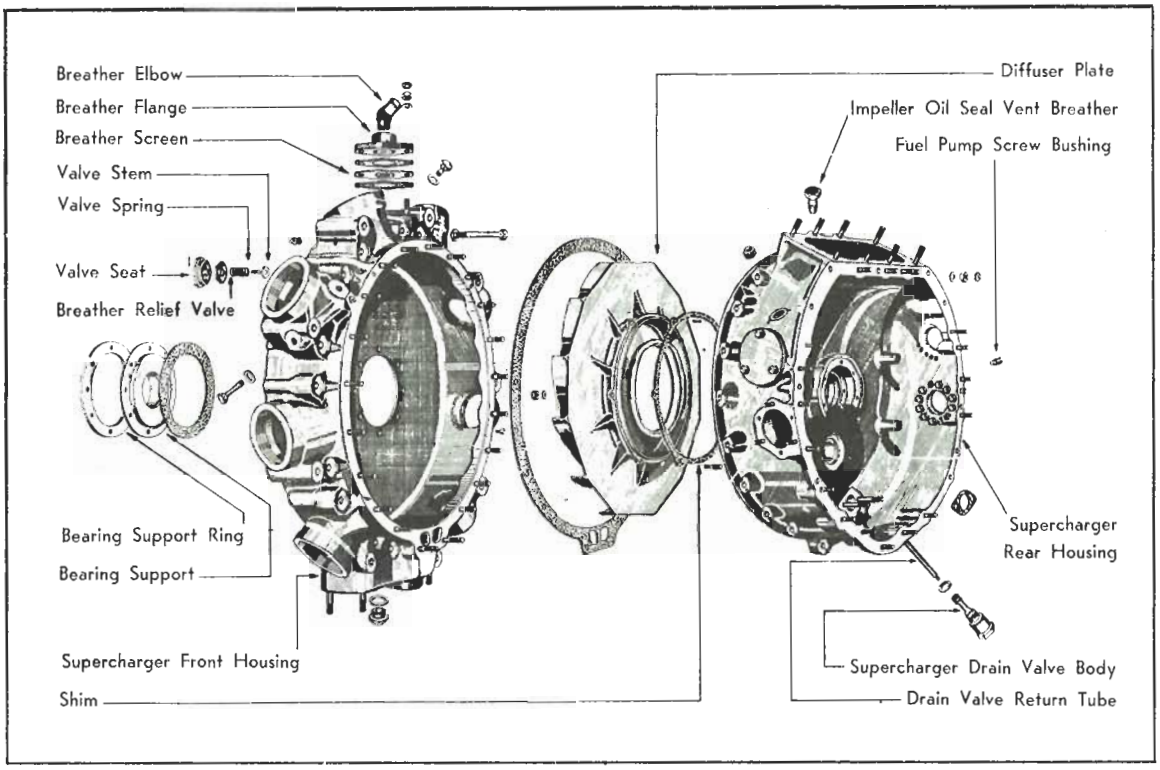



**Fig. 8. Supercharger Front and Rear Housing and Diffuser Plate.**

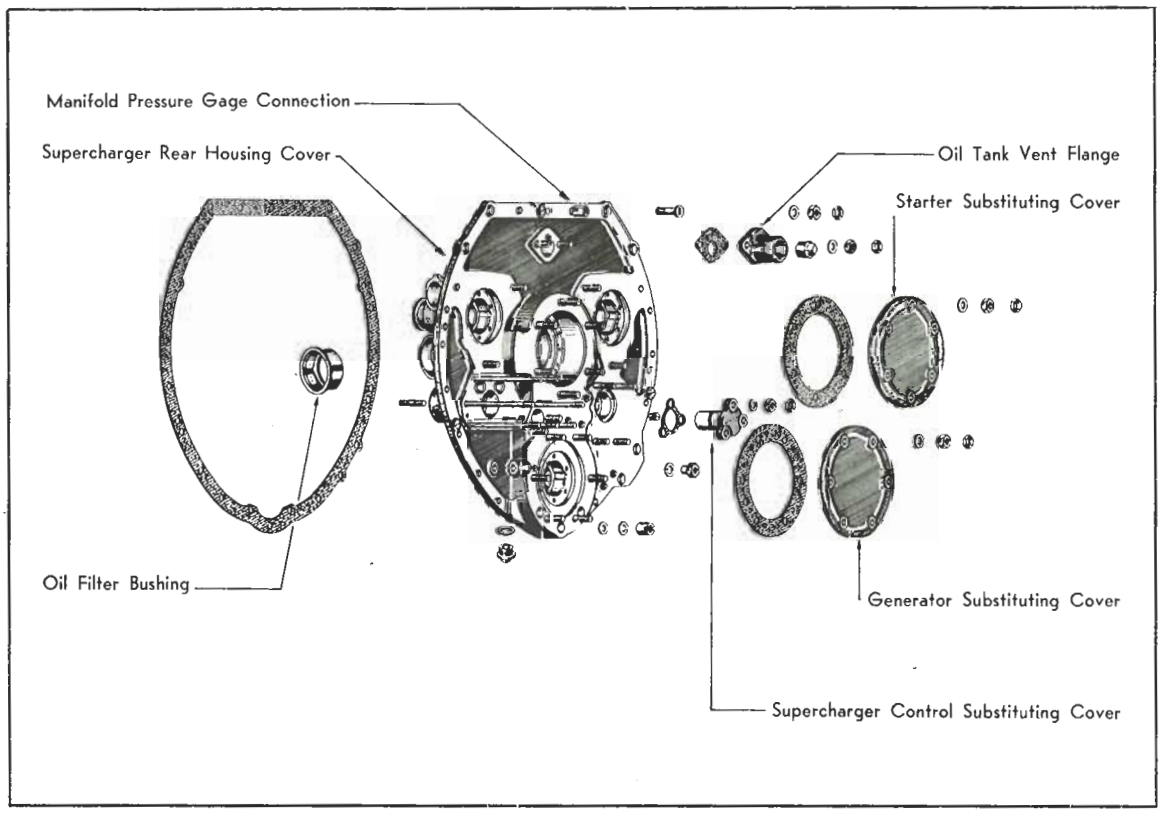



**Fig. 9. Supercharger Rear Housing Cover.**

The supercharger rear housing cover is machined from a magnesium-alloy casting in the form of a heavily-ribbed flat plate, and is secured to the rear housing by machine screws and by studs, washers, nuts, and palnuts. The rear cover provides mounting pads for the two magnetos, generator, starter, oil pump, and dual accessory drive housing. Bushings in bosses on the front face of the cover form supports for the accessory drive gears and for the rear journal of the accessory drive and starter shaft. The cover is provided with the necessary pressure oil passages for lubrication of all the accessory drives. Provision is made for an oil tank vent connection at the upper center of the cover. An oil pressure gage connection is located adjacent to the oil tank vent flange, and a manifold pressure gage connection is provided at the top flange to the right of the rear cover center line. See figure 9.

**ACCESSORY DRIVE MECHANISM** The supercharger and all accessories are driven by a forged-steel extension shaft from the rear end of the crankshaft, through an accessory drive gear which is attached to the shaft by means of a flexible-spring drive. See figure 10. The accessory drive gear is machined and casehardened from an alloy-steel forging. The accessory drive and starter shaft is splined at its front end with a coupling which is splined in turn into the rear of the crankshaft. The coupling is provided with a lock ring to insure that the coupling remains in place. The shaft is supported at its rear end by a bronze bushing in the rear cover. The rear end of the shaft has involute splines on its inside circumference which mate with a detachable started dog. Holes are drilled in the journal wall section for the main oil feed into the center-drilled shaft. Two journals on the starter shaft bear on bushings within the hollow supercharger impeller shaft. The detachable starter dog is made of alloy steel. A hollow aluminum-alloy spacer is installed between the starter dog and accessory drive and starter shaft at assembly, machined at assembly to a length which insures proper end clearance of the accessory drive shaft at the spherical oil seal ring which is supported on a pilot of the starter dog.

The accessory drive gear rotates as a unit with the starter shaft which is splined into the crankshaft. The starter, intermediate impeller, and generator drives are on the vertical center line of the supercharger rear cover. The magneto drives are located to the left and right above the starter-shaft center line. The oil pump drive and the fuel pump and dual accessory drive are to the left and right of the generator drive immediately below the magneto drives. The accessory drive gear meshes with the pinion which is integral with the intermediate impeller drive gear. The intermediate impeller drive gear meshes with the gear on the end of the impeller shaft to drive the impeller. The pinion meshes with the generator drive gear. The accessory drive gear also meshes with the fuel pump and dual accessory drive gear and with the oil pump drive gear. The oil pump and the fuel pump and dual accessory drive gears each consist of two integral gears of different diameters. In each case the gear with the larger diameter meshes with the accessory drive gear. The shafts of these gears have internal splines which drive the dual accessory gear train and the oil pump respectively. The fuel pump and dual accessory drive gear shaft has a spiral gear machined into the middle to drive the fuel pump. The right magneto drive gear meshes with the fuel pump and dual accessory drive gear on the small diameter, and the left magneto meshes with the oil pump drive gear on the small diameter. Gun-synchronizer impulse generators, if used, are driven at right angles off spiral gears cut into the magneto drive shafts.

The generator and the oil pump drive gears are machined from alloy steel forgings with integral gear and shaft. The magneto drive and the fuel pump and dual accessory drive gear assemblies have forged-steel gears attached to the flanged end of forged-steel shafts by means of cap screws.

Bushings for the accessory and starter drive shaft, the generator drive shaft, and the fuel pump and dual accessory drive shaft are machined from cast bronze material. The acces-

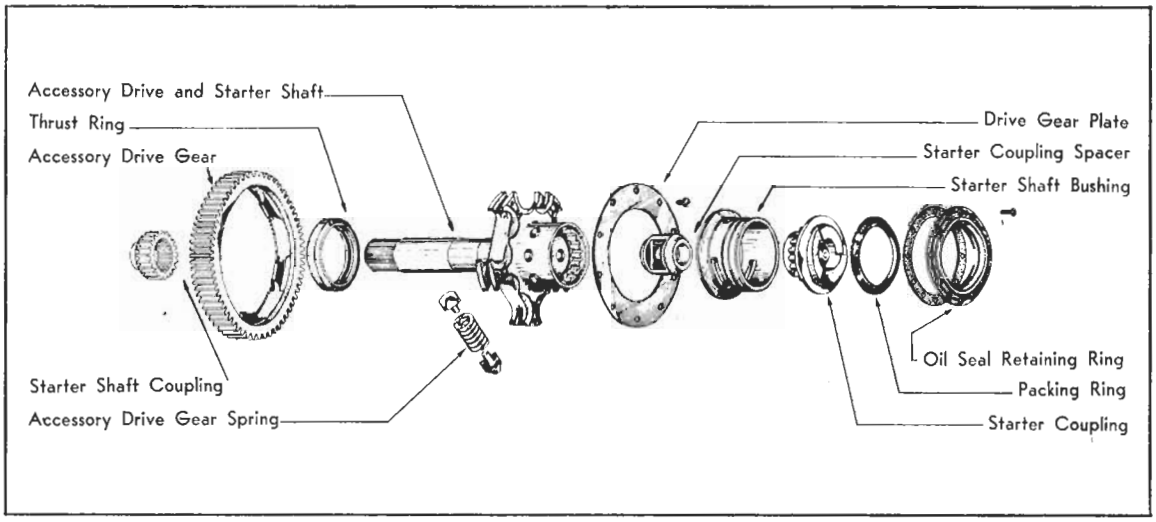



**Fig. 10. Accessory Drive and Starter Shaft.**

sory drive and starter shaft bushing is provided with three circumferential grooves and three slots to allow for the continuous flow of oil to the center of the accessory drive and starter shaft. The magneto, oil pump, and spare drive bushings are machined from aluminum alloy. Each gun-synchronizer impulse generator drive shaft operates on two bushings of sintered material which are pressed into an aluminum-alloy support. The supports are secured to the sides of the supercharger rear housing. On engines where gun synchronizers are not used, substituting covers with integral oil pressure plugs replace the gun-synchronizer impulse generator drive shaft supports. See figures 11 and 12.

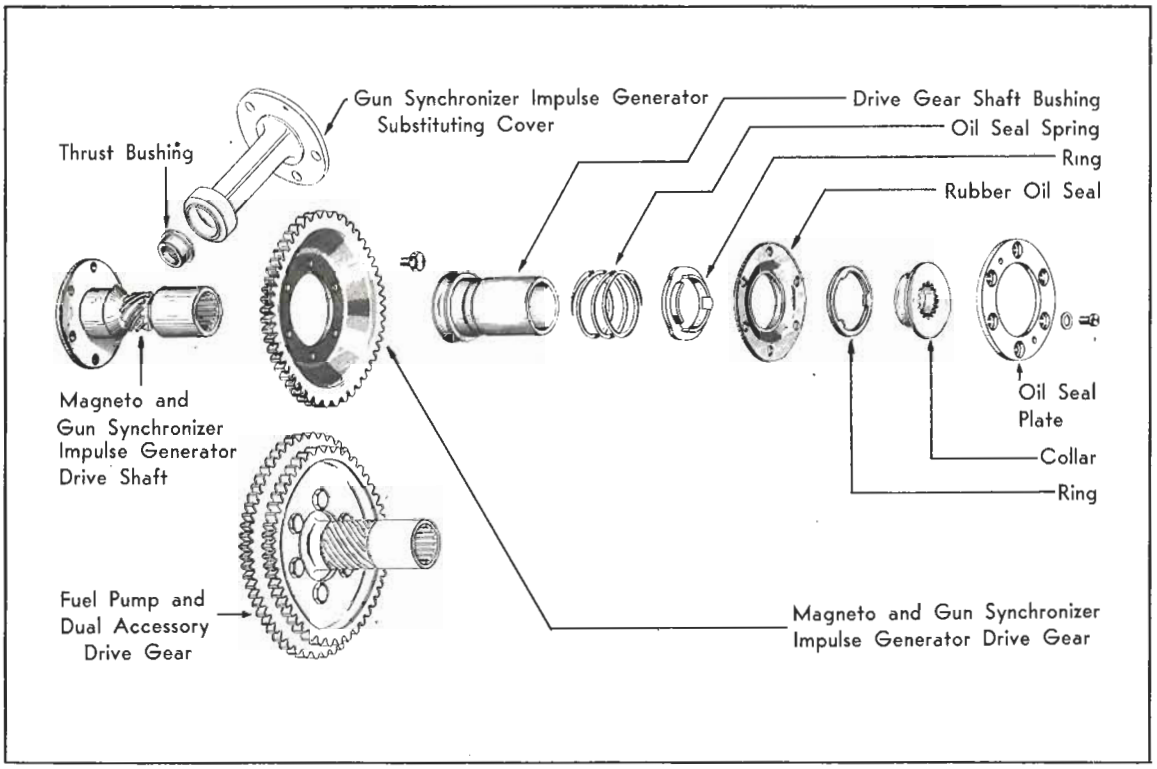



**Fig. 11. Magneto Drive Showing Gun Synchronizer Substituting Cover Plate.**

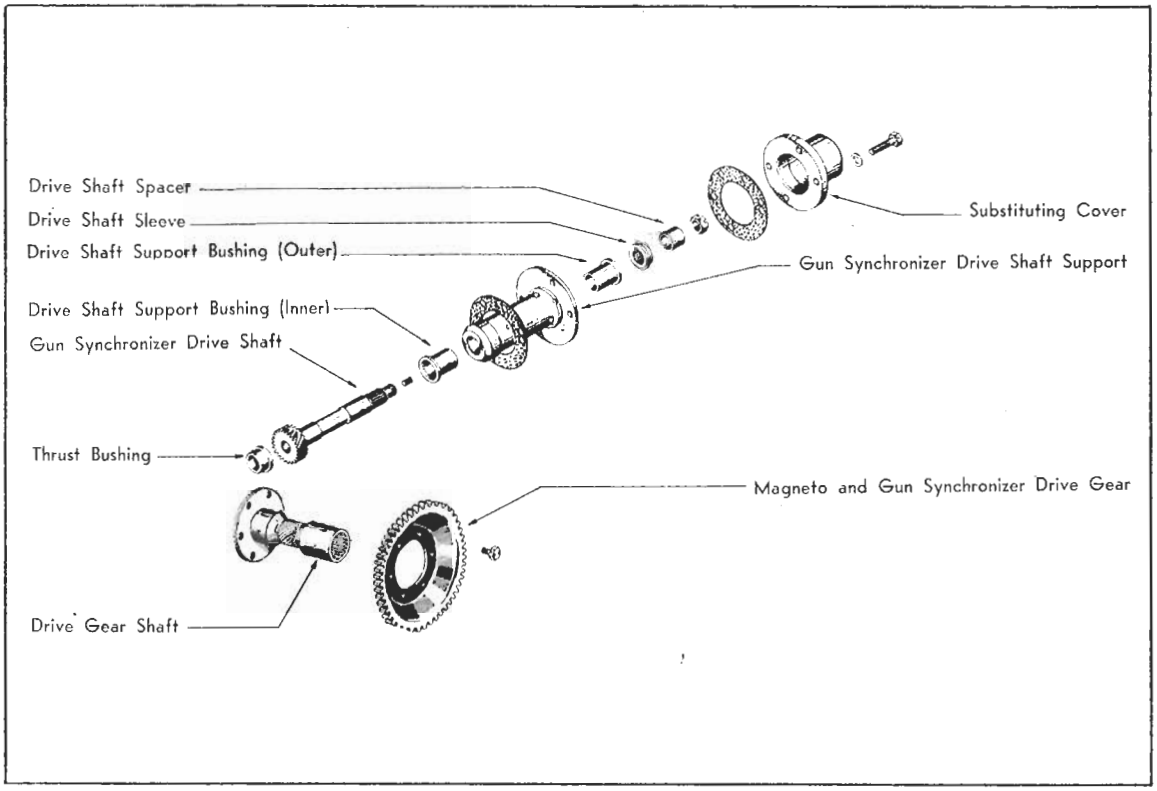



**Fig. 12. Gun Synchronizer Impulse Generator.**

The various engine accessory drives, their locations, directions of rotation, and speeds are given on the installation drawing in the back of this Overhaul Manual, and additional drawings concerning a particular installation may be obtained upon request from the Wright Aeronautical Corporation, Service Division.

**CRANKSHAFT** The crankshaft is of two-piece design and is machined from alloy steel. The front section of the shaft includes the crankpin, the front crankcheek, front dynamic damper counterweight, the front main bearing journal, and the front extension. The rear section is composed of the rear crankcheek, the rear dynamic damper counterweight, and the crankshaft rear main bearing journal. The crankpin has two oil nozzles.

The upper end of the rear crankcheek is bored to receive the crankpin, and a hole is drilled and threaded to receive the crankpin clamping screw. A slot is provided to permit clamping action when the screw is tightened.

The general appearance of the dynamic damper is the same as that of the conventional counterweight. The units consist of two counterweights, each supported on two floating pins which pass through the extended portions of the crankcheeks. The bushings on the rear counterweights are of the floating type, installed in bronze bearings, and lubricated by two oil passages drilled in the rear crankcheek. The component parts of the dampers are locked to the crankshaft by stops bolted to the crankcheeks. These stops also limit the movement of the counterweights when the crankshaft is rotated by hand.

The crankpin and drive shaft are bored for lightness throughout, except at the rear end of the crankpin where a web is left to prevent distortion when the rear crankcheek is clamped in position. A plug is pressed into the front end of the crankpin bore and secured by a drilled cap screw, which also serves as an oil metering jet. See figure 13.

The crankshaft is supported in the crankcase by a roller bearing directly forward of the front crankcheek and by a roller bearing

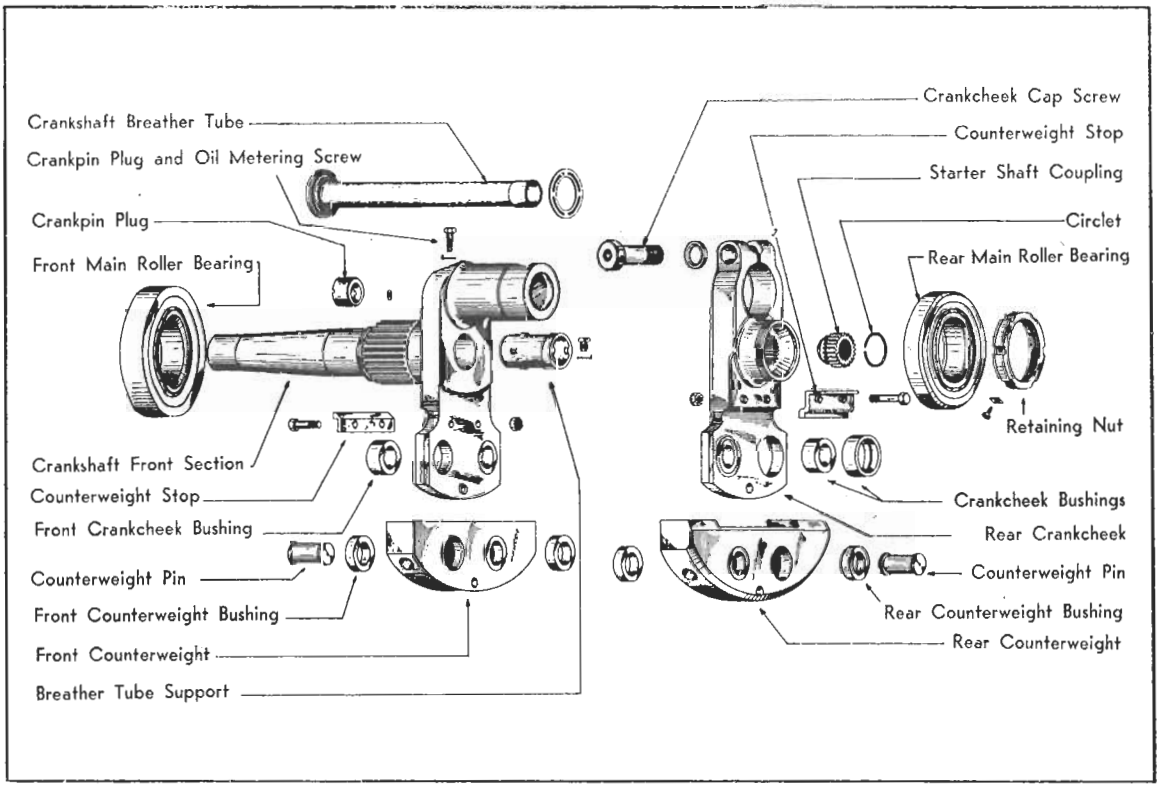



**Fig. 13. Crankshaft.**

behind the rear crankcheek. Both bearings are of the demountable type, the front bearing incorporating sixteen rollers and the rear bearing, eighteen rollers.

The crankshaft extends forward inside the propeller shaft and rides on two bushings, one at the front and one at the rear of the propeller shaft. Engines using crankshaft breathing incorporate a breather tube in the hollow crankshaft. The rear of the breather tube has an oiltight fit in a support at the front crankcheek, while the flange at its propeller end seats on the propeller shaft front bushing. The annulus thus formed between the breather tube and the crankshaft acts as a reservoir for engine oil. The flange is drilled for two sets of holes to allow for the unrestricted flow of both hydro-low and hydro-high pressure oil to the propeller. A gasket, adapter, and retaining nut complete an oiltight passage for the hydro-oil to the propeller. A plug is used on the adapter to blank off the oil passages when a non-hydraulic propeller is used.

If crankshaft breathing is not used, this tube and its supports are not included in the assembly, and the front of the propeller shaft is sealed with a plug. Breathing then takes place through cored air passages in the supercharger front section to a vent on the top of the section.

**PROPELLER SHAFT AND REDUCTION GEAR** The propeller shaft of alloy steel is a short, straight shaft, hollow throughout its length. The shaft for the .666 reduction gear ratio engine has six pinion arms forged integrally at the rear end. The end of each arm is drilled and fitted with bronze bushings which carry the reduction gear pinions. The arms are drilled for lubrication of the bushings. See figure 14.

The shaft for the .5625 reduction gear ratio is slightly different. The rear end of the shaft has a large flange forged integral with the shaft. The flange is drilled for attaching bolts, and a carrier ring is fastened to it by means of nuts and bolts. The carrier ring incorporates

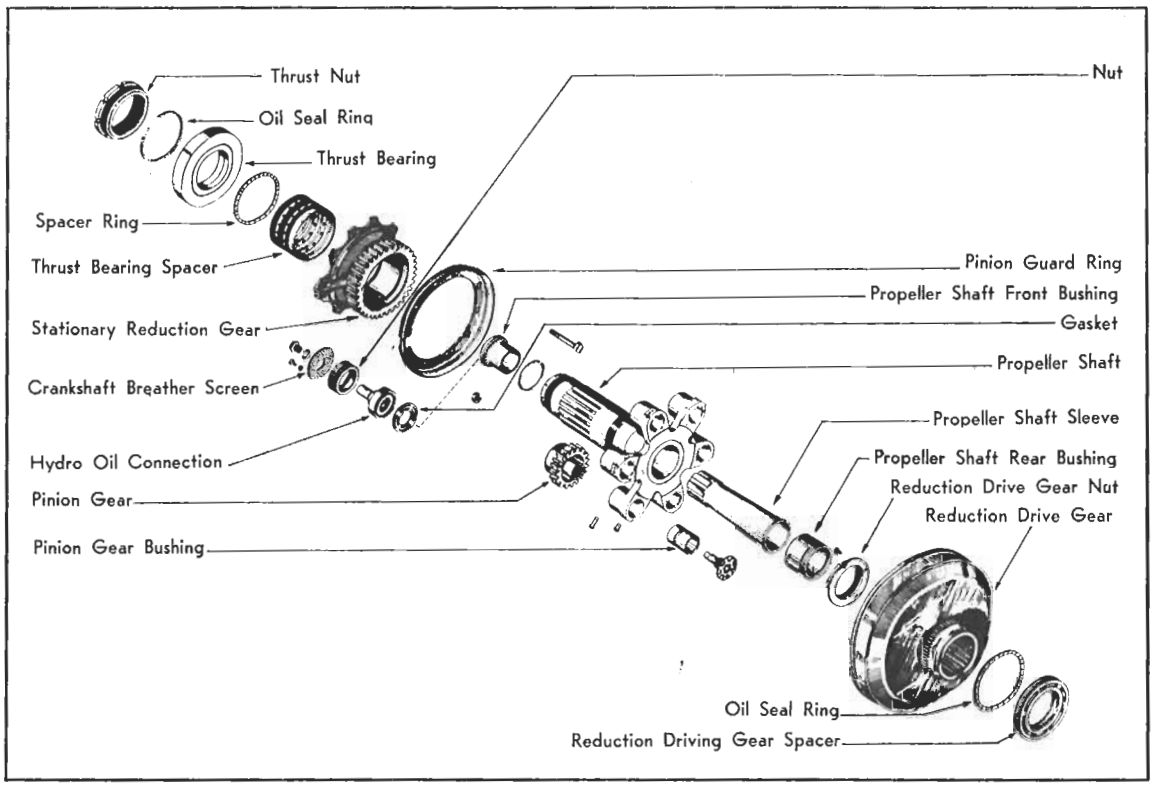



**Fig. 14. 3:2 Reduction Gear.**

20 trunnions, each of which supports a bushing and pinion. See figure 15.

Each propeller shaft is threaded to receive the thrust nut, and the front end is splined to receive the propeller hub. Provision is made at the front end for a hydromatic propeller.

Reduction gearing is of the planetary type, consisting essentially of a reduction driving gear splined to the crankshaft, pinion gears mounted on the arms of the propeller shaft or on a carrier ring mounted on the propeller shaft, and a stationary gear secured to the front section. The pinion gears mesh with the reduction driving gear and the stationary gear in the front section.

The reduction driving gear is provided with a magneto timing scale ranging from 0 deg. to 35 deg., and scribe lines are provided to indicate the top center positions of the cylinders.

**TORQUEMETER** The Wright torquemeter measures the torque reaction on the stationary gear, sometimes referred to as the "sun" gear, of the propeller reduction gearing. The torque type stationary reduction gear is called the "stationary substituting gear," since it differs from the stationary gear used in non-torquemeter reduction gearing. This stationary substituting gear has a ball race on its inside circumference and a single integral torque arm. An adapter bolted to the crankcase front section has a similar ball race on its outside circumference. The stationary substituting gear is assembled to the adapter by means of a number of balls inserted between the races, permitting relative motion between the gear and the adapter and acting as an anti-friction device.

The outer end of the torque arm acts on a balancing valve enclosed in a conical valve housing which is bolted to the crankcase front section. The valve is actuated in one direction by the torque reaction of the stationary substituting gear and is balanced in the other direction by oil pressure on the valve head. The entire oil displacement of a small high-pressure oil booster pump installed on the governor drive housing is conducted through drilled passages in the crankcase front section

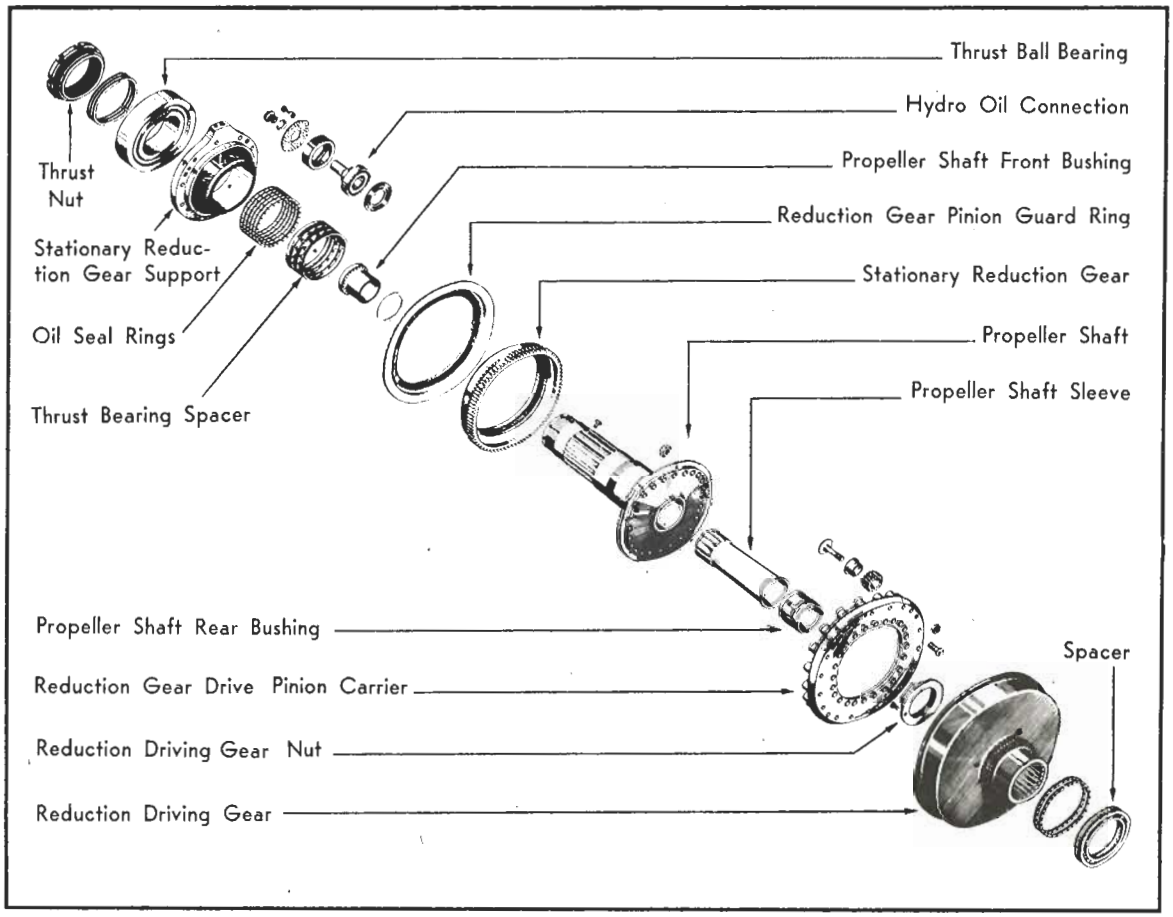



**Fig. 15. 16:9 Reduction Gear.**

to the torquemeter valve housing. The stationary substituting gear is kept from turning by this oil pressure acting on the head of the valve, the force being transmitted through the torque arm. There is only slight relative motion between the stationary substituting gear and the adapter.

When the engine is operating, the torque reaction of the stationary substituting gear causes a slight outward movement of the valve and an increase in the oil pressure on the valve head. Oil drain slots or ports in the sleeve in which the valve moves are covered by the valve until the booster pump builds up sufficient oil pressure to overcome the torque reaction and produce a slight inward movement of the valve. This inward movement of the valve partly opens the metering slots. Oil escapes through these metering slots and is conducted to the crankcase. The oil pressure on the head of the valve decreases until the torque reaction is again just sufficient to overcome the oil pressure, and another slight outward movement of the valve is produced. This cycle is repeated until a point of equilibrium is reached.

An oil pressure gage line is tapped into the valve housing cover at the valve head and is led to a special oil pressure gage calibrated to indicate brake mean effective pressure.

**CONNECTING RODS** The connecting-rod assembly consists of a master rod and eight articulated rods attached to the master rod by knuckle pins. The rods are fabricated from a special, I-section, alloy-steel forging, heat-treated for high strength and machined all over. Both the knuckle-pin end and the piston-pin end of the articulated rods are fitted with bronze bushings.

The web of the master-rod shank is parallel with the crankpin axis, and the flanges of the shank blend smoothly into the knuckle-pin

flanges. A split-type bronze bushing is expanded and spun into place in the piston-pin end of the master rod. The crankpin end of the master rod is provided with a steel bushing lined with copper-lead bearing metal on its inside circumference and is also lead and indium-plated for increased life.

A bearing end-seal assembly is used on the master rod to improve the crankpin-bearing lubrication by providing a seal against excessive oil leakage. The end-seal assembly consists essentially of a steel knuckle-pin lock plate, a spacer spring, and end-seal disks for both the front and rear ends of the master-rod bearing. The knuckle pin lock, which is bolted to the front end of the knuckle pins, has splines that mate with the forward end of the master-rod bearing shell to prevent the latter from turning in the rod. A recess is machined into the front side of the knuckle-pin lock plate for the spacer spring and end-seal disk. A collar on this disk fits into the recess, and the spacer spring is located inside the collar. The front face of the disk is held snugly against the front crankcheek by the spacer spring to form an oil seal. The oil seal is completed by a carbon steel spacer, which fits over a boss on the rear side of the master rod. See figure 16.

The master rod operates in No. 1 cylinder in C9GC series engines.

**KNUCKLE PINS** The knuckle pins are made of chrome-alloy steel with nitrided bearing surfaces which have been finished by lapping and polishing. The front ends of the knuckle pins are drilled and threaded to receive cap screws which bolt the lock plate to the knuckle pins. Flat plate locks retain the cap screws. A lug on the forward end of the knuckle pin engages with the edge of the lock plate to prevent rotation of the pin in the master rod. The hollow center of the pin receives oil through passages in the lock plate and lock screw, and the oil is fed to each articulated rod bushing through two drilled holes in each knuckle pin. See figure 16.

**PISTON PINS** Piston pins are made from alloy steel with a casehardened bearing surface. They are of tubular design, ground smooth internally and externally, and

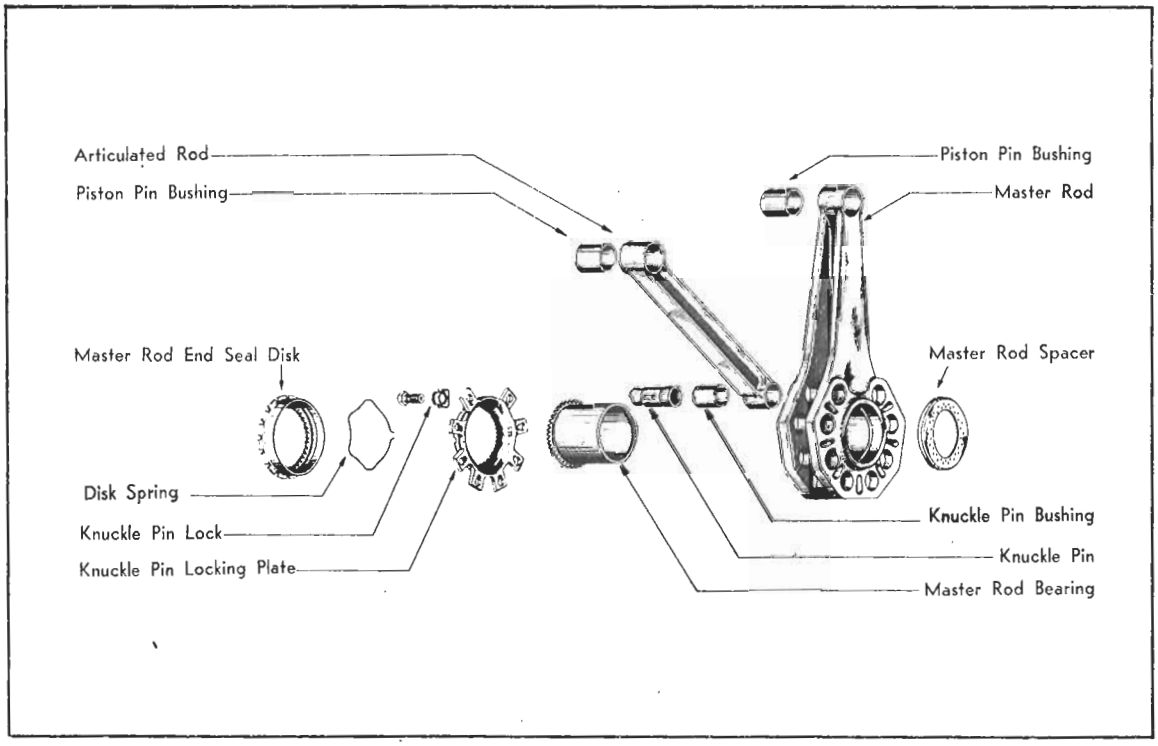



**Fig. 16. Master Rod Showing End Seal Disk, Articulated Rod, Lock Plate, and Spacer.**

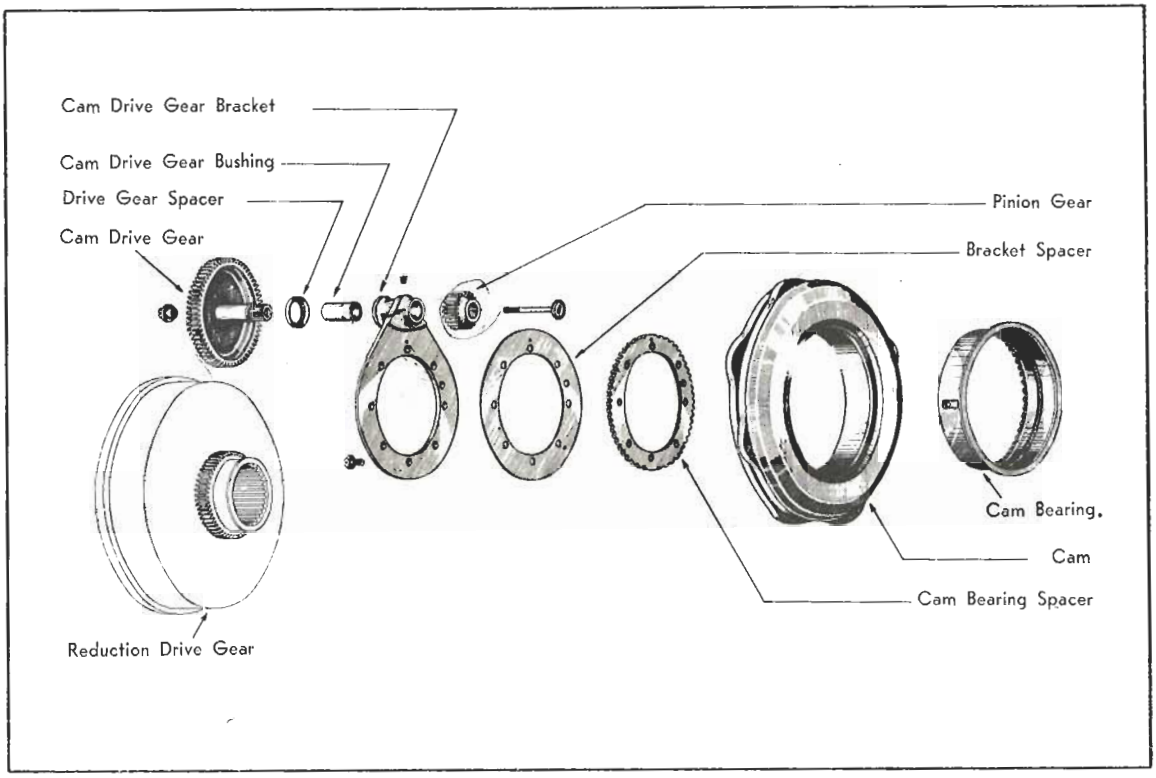



**Fig. 17. Cam and Cam Drive.**

lapped on the outside circumference to provide a finished bearing surface. Coil-spring type retainers at each end of the piston pin lock it in place in the piston. See figure 4.

**PISTONS AND RINGS** The pistons are the full-trunk type, machined from aluminum-alloy forgings. Fins are machined on the inside of the skirt on the thrust and anti-thrust sides. The pistons are recessed on top to provide adequate valve head clearance.

The piston assemblies are of the standard "Uniflow" type. The top three ring grooves are slightly tapered. Three identical wedge-type rings are assembled in the grooves. The three lower rings and grooves are of rectangular cross section with the bottom ring inverted, so that it pumps oil along the cylinder wall. Grooves 4 and 5 are drilled for oil drain holes. See figure 4.

**VALVE OPERATING MECHANISM** The operation of the valves is accomplished by means of a cam which is located in the crankcase front section and consists of a hardened-steel ring with two sets of cam lobes on its outside circumference. This ring is mounted on the hub which is integral with the crankcase front main section. An intermediate cam drive gear, intermediate governor drive gear, and a cam drive pinion are mounted on a bracket which is secured to the hub with six cap screws. The driving power for these gears is taken from the cam drive which is machined on the hub of the reduction drive gear. The cam drive gear bracket is drilled to provide pressure lubrication to the bushing.

The cam lobes acting on the cam follower rollers, or valve tappets, actuate the push rods, and they in turn operate the rocker arms which open the valves. See figure 17.

The tappets, or cam followers, and the tappet guides are evenly spaced around the outside wall of the crankcase front section. The tappets are of hardened steel and are given a close sliding fit in the guides to prevent oil leakage. The tappet and guide assembly is held together by a circlet which fits into a groove machined into the push-rod end of the tappet. A steel cup or socket is located in the

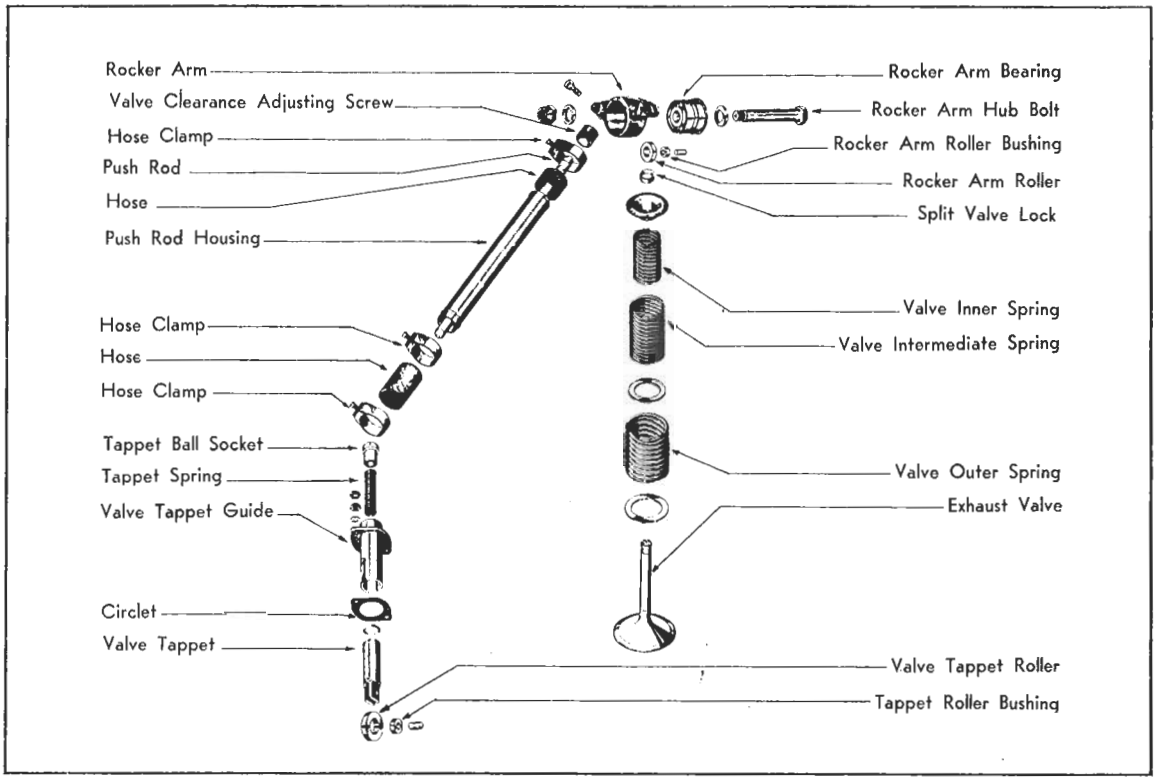



**Fig. 18. Valve Mechanism.**

push-rod end of the valve tappet. For lubrication purposes, this socket is given a close sliding fit in the tappet and is held against the push-rod ball end by a coil spring inside of the tappet. The tappet assemblies located above the horizontal center line of the engine are lubricated by pressure oil. The remainder of the tappets are lubricated by gravity oil. The tappet guides are slotted on the forward side of the push-rod end to permit the removal of the push rods without removing the rocker arms. The roller end of the tappet is slotted to receive the valve tappet roller which rotates on a floating pin.

The push rods are of heat-treated, seamless steel tubing with hardened-steel ball ends pressed into each end. The push-rod housings are of annealed, seamless dural tubing. Each housing is connected to the tappet guide and to the connection at the rocker box with oil-tight hose connections.

The rocker arms are I-section and are machined from steel forgings. They are mounted on double roller bearings, the inner races of which are clamped in the rocker box by a through bolt. The valve end of the rocker arm is forked to carry a roller operating on a hub and a pin riveted in the arm. The push-rod end of the rocker arm is provided with a tappet-clearance adjusting screw and an adjusting-screw lock screw. See figure 18.

**VALVES AND VALVE SPRINGS** The intake valves are of the tulip type and the exhaust valves are of the mushroom type. Both are machined from forgings of heat-resisting steel. Valve-face angles are 44 deg. 45 min. to 45 deg. 0 min. for both intake and exhaust.

The exhaust valve is hollow and contains a cooling medium, while the intake valve stem is smaller in diameter and of solid cross section. A stellite seat is welded to the exhaust valve to improve the wearing qualities.

Each valve is fitted with three concentric coil springs. The intake and exhaust valve springs are interchangeable. The inner spring seats on the shoulder of the valve guide, while the intermediate and outer springs seat on steel washers which rest on machined surfaces in the cylinder head. A shouldered washer is provided at the outer end of the springs and

is locked at the valve tip by a tapered, split lock ring. See figure 18.

**SUPERCHARGER** The supercharger, which is of the centrifugal type, consists of an impeller or blower, diffuser plate, and distribution chamber. The impeller is machined from a duralumin forging. It is mounted on a hollow steel shaft with one plain bushing pressed inside each end. The impeller shaft is concentric with the accessory drive and starter shaft which provides journals for the two internal plain bushings in the impeller shaft.

The distribution chamber, an annular passage in the supercharger front housing, surrounds the impeller and the diffuser plate. The intake pipes are attached to this chamber through ports radial to its circumference.

The impeller shaft is located axially by a flat thrust washer and a spherical thrust ring at the rear of the impeller shaft gear and by a steel retainer attached to the supercharger rear housing. A bronze washer is provided in front of the impeller shaft gear and a laminated shim beneath the steel retainer attaching flange for end clearance adjustment. The impeller operates with the inlet side facing the rear of the engine. See figure 19.

Around the impeller shaft in the supercharger front housing is an oil sleeve with piston-ring type seals which provide an oil seal to prevent the supercharger from drawing oil out of the crankcase. An annular groove at the midpoint of this sleeve is connected through a blank impeller spline to the groove of a similar oil seal housed in the supercharger rear section. A vent from the rear sleeve to the atmosphere breaks the suction and prevents the leakage of oil through these seals to the supercharger.

A drain passage is provided from the lower rear portion of the supercharger inlet chamber out through the supercharger rear housing to prevent the accumulation of excess fuel. A check valve stops air from being drawn in through this passage. A restricted air bleed is provided, however, through a small diameter tube that leads up through the drain passage to the impeller inlet area. During engine operation any fuel that runs down the walls of the supercharger inlet passage collects in the drain passage on top of the check valve which is held closed by the suction of the supercharger. Four holes are provided in the air bleed tube to permit the fuel to be drawn in and atomized for redelivery to the impeller.

**SINGLE-SPEED SUPERCHARGER** The single-speed supercharger drive unit consists of an impeller drive and pinion gear (7.0:1 ratio) which rotates in a bushing in the supercharger rear housing cover at one end and another bushing in the supercharger rear housing web at the other end.

The drive for the impeller is from the acces-

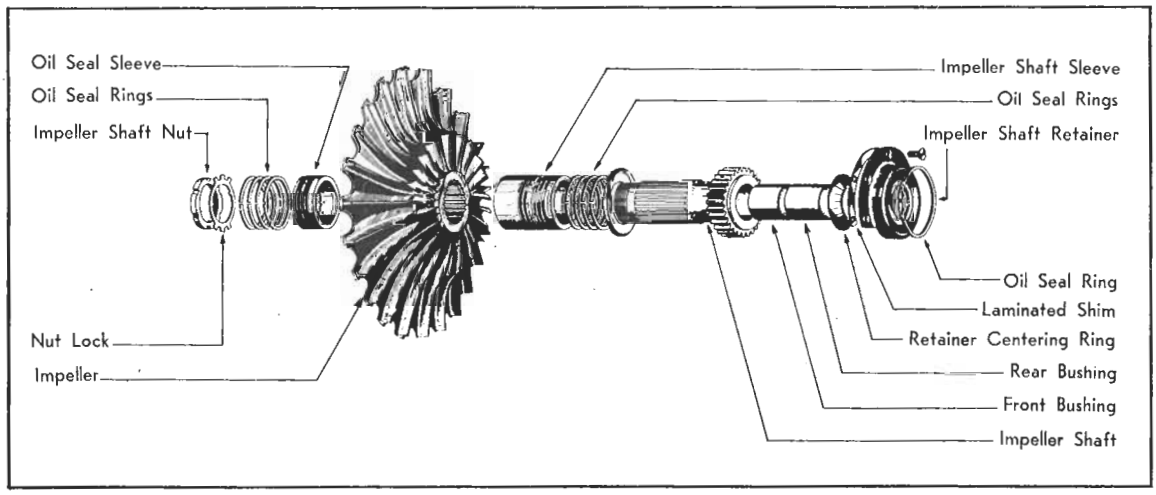



**Fig. 19. Supercharger Impeller and Impeller Shaft.**

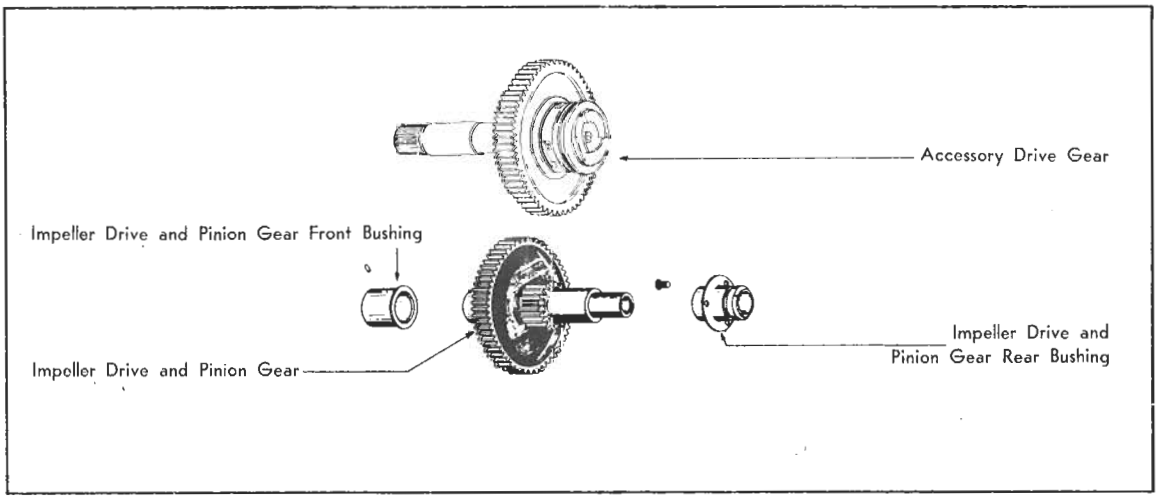

Accessory Drive Gear
Impeller Drive and Pinion Gear Front Bushing
Impeller Drive and Pinion Gear
Impeller Drive and
Pinion Gear Rear Bushing

**Fig. 20. Single-Speed Supercharger Drive.**

sory drive gear to the impeller drive and pinion gear to the impeller gear. See figure 20.

**TWO-SPEED SUPERCHARGER DRIVE (PLATE-CLUTCH TYPE)** The two-speed supercharger drive plate-clutch unit, available on some C9GC models, consists essentially of a high-speed ratio drive supplemented by a planetary-gear reduction system which, when engaged, produces the low-speed ratio drive. A plate clutch is housed in the supercharger rear housing cover to effect the low-ratio drive while a second plate clutch, housed in the impeller drive gear, actuates the high-ratio drive. The high-ratio clutch revolves with the impeller drive gear while the low-ratio clutch remains stationary in the supercharger rear housing cover. The speed change is obtained by means of a manually operated control valve which regulates the flow of oil to either clutch, thereby engaging that particular clutch.

The two-speed control valve assembly, which is attached to the supercharger rear housing cover, is a push-pull piston-type selector valve. The selector valve is held in the LOW-ratio position by the action of a built-in spring and in the HIGH-ratio position by manual control in the cockpit.

The operation of the drive through the low-ratio gear is as follows:

When the manual control is placed in the low-speed position, the two-speed control valve is in the extreme forward position. Engine oil under pressure is led from a passage in the rear cover, through the control valve, and into a chamber behind the low-speed clutch piston by way of another drilled passage.

The low-speed clutch piston is moved forward by the oil pressure which in turn presses the clutch plates and disks together. As the clutch plates and disks engage, the low-speed planetary sun gear becomes stationary, thus obtaining the low ratio through the planetary gear drive. At the same time the high-ratio clutch plates and disks are disengaged by a coiled spring built into the clutch. In low ratio, therefore, the drive is from the accessory drive shaft gear to the small bell-shaped intermediate driving gear, through this gear to the five planetary pinion gears and intermediate impeller drive shaft, on which the pinion gears are mounted; through this shaft, which is splined to the impeller drive gear at the forward end, and thence to the impeller shaft gear. See figure 21.

The high-gear ratio is obtained by means of engine oil pressure in the following manner:

With the control valve in the extreme rearward position, engine oil passes through the control valve from a drilled passage in the rear cover; then through another drilled passage in the cover into the hollow intermediate impeller drive shaft, where it passes through a check valve in the forward end of the shaft; then through drilled holes in the shaft and into the chamber behind the high-speed clutch

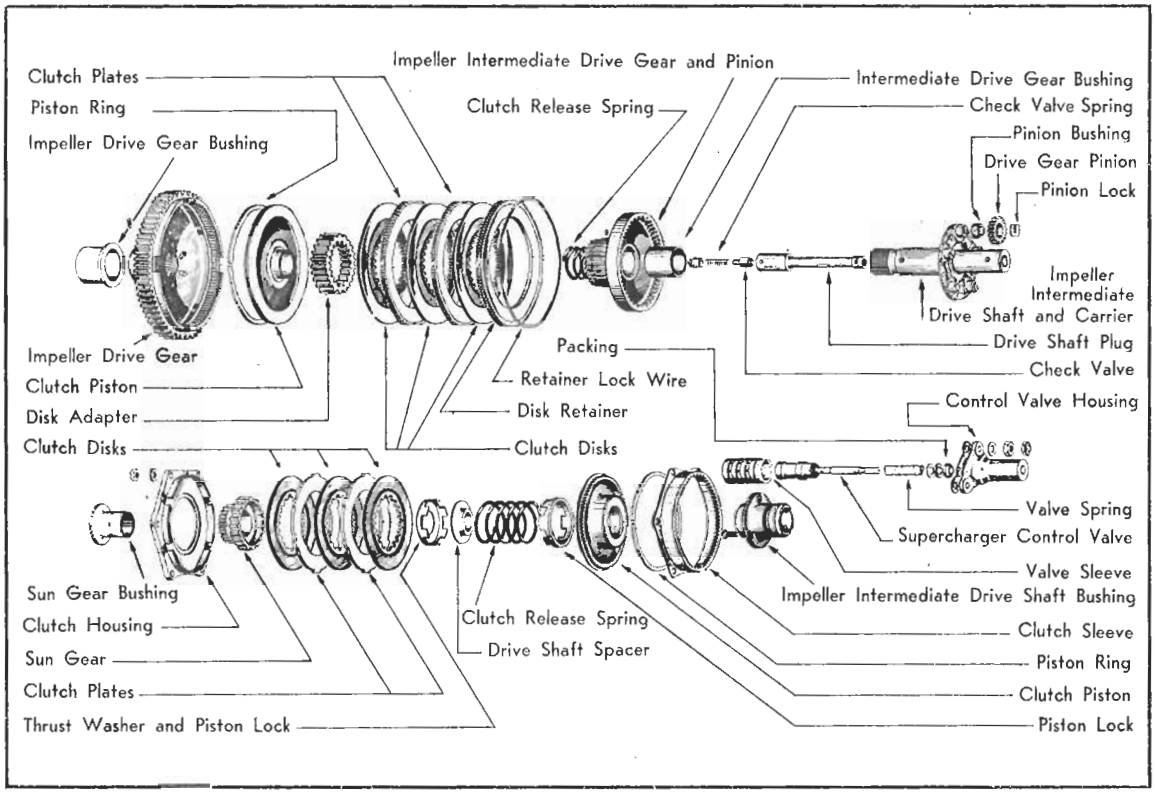



**Fig. 21. Two-Speed Plate Clutch Supercharger Drive.**

piston. The piston moves toward the rear of the engine under the action of the oil pressure, thus engaging the clutch plates and disks and locking the bell-shaped, intermediate impeller drive gear to the impeller drive gear through a splined adapter in the high-ratio clutch.

Changing the position of the selector valve from low ratio to high ratio not only supplies oil to operate the high-ratio clutch but also cuts off the oil flow to the low-ratio clutch, at which time the action of the spring built into the low-ratio clutch releases clutch plates, disks, and piston. As the piston moves toward the rear of the engine, oil in the chamber behind the piston is forced out through a passage in the rear cover and drains into the supercharger rear housing. The planetary sun gear is now disengaged, thus permitting the planetary reduction gears to turn freely and the low-speed clutch becomes inoperative.

In high ratio the drive is from the accessory drive gear to the propeller end of the bell-shaped intermediate impeller drive gear, from the intermediate impeller drive gear through the high-ratio clutch and gear to the impeller shaft gear and shaft.

**TWO-SPEED SUPERCHARGER DRIVE (ROLLER-CLUTCH TYPE)** The two-speed, roller-clutch supercharger drive consists of a roller and cam clutch in low ratio and a plate clutch in high ratio. The essential difference between this and the earlier two-speed double hydraulic plate clutch is the use of a stationary plate clutch in high-speed ratio, eliminating the rotating plate clutch. The drive in low-speed ratio is accomplished through a roller and cam assembly instead of a planetary pinion drive. See figure 22.

The roller clutch in the low-speed ratio supercharger drive consists of a steel cam which acts as the inner race for 10 steel rollers. The low-speed impeller drive cam is splined on its inside circumference to the intermediate impeller drive shaft and the rollers are held in place on the outside circumference of the cam by a bronze cage and a steel retainer. The steel retainer splines on its propeller end to the antipropeller end of the inter-

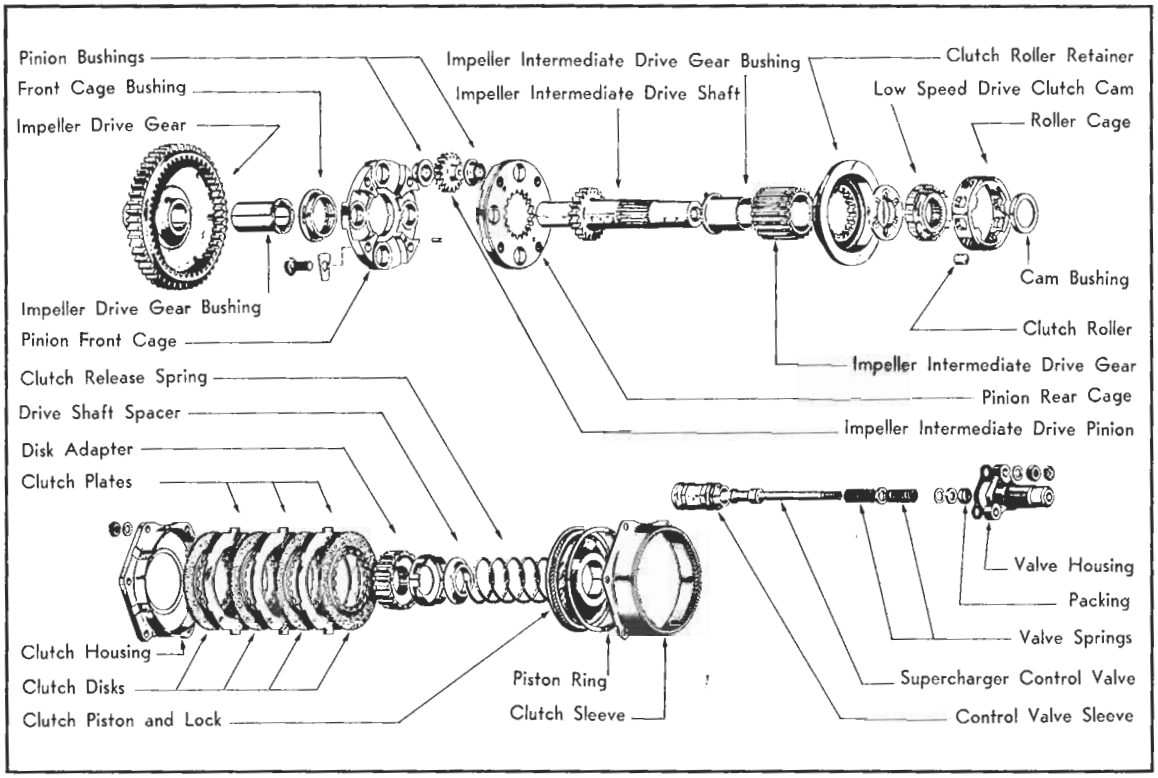



**Fig. 22. Two-Speed Roller Clutch Supercharger Drive**

mediate impeller drive gear. In turn, the intermediate impeller drive gear splines on its propeller end to the inside circumference of the rear half of the intermediate impeller drive pinion cage.

The intermediate impeller drive gear and bushing ride on a journal at the approximate center of the intermediate impeller drive shaft. The four intermediate, impeller drive planetary pinion gears in the intermediate impeller drive pinion cage mesh with the sun gear, which is integral with the intermediate impeller drive shaft, and with the internal teeth of the impeller drive gear. The impeller drive gear and bushing ride on a journal at the propeller end of the intermediate impeller drive shaft. The outside circumference of the impeller drive gear journal rides in a bushing in the supercharger rear housing, and the external teeth of the gear mesh with the gear teeth on the antipropeller end of the impeller shaft.

The hydraulic multiplate clutch for the high-speed ratio drive is located at the antipropeller end of the intermediate impeller drive shaft in the supercharger rear housing cover.

The high-speed piston seats on the outside circumference of a bushing which is pressed into the rear cover. The piston ring seats against the high-speed impeller drive clutch sleeve, which is inserted in the rear cover, and the splines on the outside circumference of the piston mate with those on the inside circumference of the high-speed, impeller drive clutch sleeve. Forward of the piston is a high-speed clutch disk, which is splined on its inside circumference to the intermediate impeller drive clutch adapter, which in turn is splined to the intermediate impeller drive shaft. Directly forward of the high-speed clutch disk is a high-speed clutch plate which splines on its outside circumference to six notches in the high-speed, impeller drive clutch housing. There are four clutch disks and three clutch plates alternately arranged in the above manner. Forward of the last clutch disk is the high-speed, impeller drive clutch housing. The housing is attached to the supercharger rear housing cover with six washers, nuts, and cotter pins, thus retaining the high speed clutch assembly.

Pressing against the forward face of the

high speed piston is the high-speed, clutch release spring. The propeller end of this spring seats on the high-speed clutch spacer. The purpose of this spring is to disengage the piston, plates, and disks when the oil pressure is released and the high-speed clutch is not in operation.

The roller-clutch, two-speed supercharger drive assembly operates either in high or low-speed ratio, there being no neutral position in which both the high and low-speed ratio drives are disengaged at the same time, and no position in which they are both engaged at the same time.

In either supercharger drive ratio, the primary gear train is from the accessory drive and starter shaft gear to the intermediate impeller drive gear, thence through either the low or high-speed clutch to the impeller drive gear, and then to the impeller shaft.

In low-speed ratio operation, the drive is as follows: From the accessory drive and starter shaft gear to the intermediate impeller drive gear which is splined on its antipropeller end to the roller retainer. Because of the inertia force exerted by the impeller on the impeller drive gear, the intermediate impeller drive pinions rotate, and in turn, cause the intermediate impeller drive shaft and integral sun gear to rotate. The intermediate impeller drive shaft turns the roller clutch cam in the same direction and at a higher speed than the roller retainer. This relative difference in speed between the cam and the roller retainer causes the rollers to rise up on the lobes of the cam and lock the roller retainer, the rollers, and cam as a single unit. Because the roller-clutch assembly is now operating as a single unit, the intermediate impeller drive pinions, the sun gear, and the impeller driving gear must also operate as a unit. The drive for the low-speed ratio clutch is, therefore, operating directly from the accessory drive and starter shaft gear, through the intermediate impeller drive gear to the impeller drive gear, and thence to the impeller shaft. This results in the desired impeller to crankshaft speed ratio for low supercharger operation.

In high-speed ratio operation the drive is as follows: From the accessory drive and starter shaft gear to the intermediate impeller drive gear, which is splined on its propeller end to the rear half of the intermediate impeller drive pinion cage and on its antipropeller end to the roller retainer.

Because of engine oil pressure, which is distributed to the chamber behind the high-speed piston by the oil control valve, the piston moves forward, compressing the high-speed clutch release spring and locks the clutch disks, which are splined indirectly to the intermediate impeller drive shaft, hence to the stationary clutch plates. With the intermediate impeller drive shaft and the low-speed impeller drive cam held stationary, the roller retainer rotates around the cam, thus freeing the rollers and disengaging the low-speed ratio clutch. This results in the intermediate impeller drive pinion gears revolving around the intermediate impeller drive shaft gear and driving the impeller drive gear, which in turn, drives the impeller shaft.

As the pinion gears drive the impeller drive gear through its internal teeth, and the impeller drive gear in turn drives the impeller shaft from its external teeth, the desired impeller to crankshaft speed ratio for high-speed supercharger clutch operation is obtained.

Selection of impeller to crankshaft speed ratios is accomplished by means of a push-pull oil control valve. The oil control valve operates inside the oil control valve sleeve which is pressed into the supercharger rear housing cover. Concentric about the valve stem, and inside the oil control valve housing, are two springs, separated by a washer which seats against a spacer in the housing and limits the movement of the valve. The oil control valve for the roller-clutch assembly is placed in the extreme forward or "IN" position for low-speed ratio drive, and in the extreme rearward or "OUT" position for high-speed ratio drive.

The operating oil for the high-speed ratio drive is supplied through a drilled passage in the rear cover to an annulus around the control valve sleeve.

When the low-speed ratio drive is in operation, no operating oil pressure is necessary. The low-speed ratio drive is operated by the roller clutch assembly as previously described.

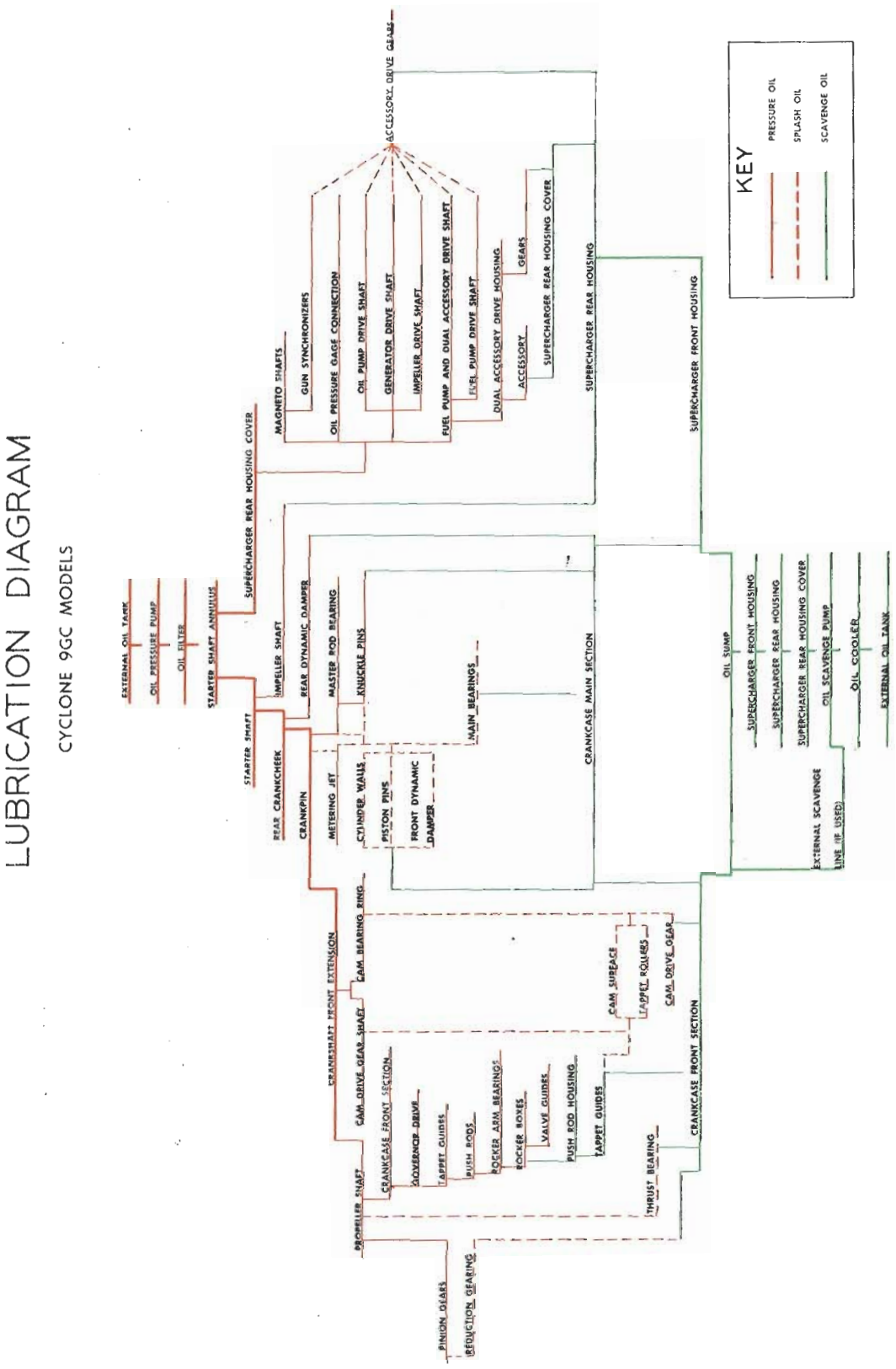



**Fig. 23. Lubrication Diagram.**

However, when the high-speed ratio drive is in operation, oil pressure is required to engage the high-speed clutch piston, disks, and plates. This pressure oil is obtained by moving the oil control valve to the rearward or "OUT" position. This allows the engine pressure oil to flow around the annulus cut in the oil control valve to a drilled passage in the oil control valve sleeve and through a mating drilled passage in the rear cover to the chamber behind the high-speed piston.

When the oil control valve is shifted back to the low-speed ratio drive position, it blanks off the pressure oil passages to the chamber behind the high-speed piston and opens drain passages through the valve and the rear cover, thus releasing the pressure oil in the chamber behind the high-speed piston. This releases the piston, disks, and plates with the aid of the high-speed clutch release spring.

**LUBRICATION** The lubrication system is of the full pressure type except for the cylinder walls, piston pins, crankshaft main bearings, and propeller shaft thrust bearing, all of which are lubricated by splash. See figure 23. Oil is carried in an external tank not furnished with the engine but with the plane. The oil is drawn from the supply tank by a pump mounted on the left side of the rear cover. See figure 24. The oil pump is provided with a spring loaded piston-type pressure relief valve which lifts from its seat, when the desired pressure is exceeded, to bypass oil to the inlet side of the oil pump thus maintaining the desired pressure. Pressure regulation is accomplished by turning the ad-

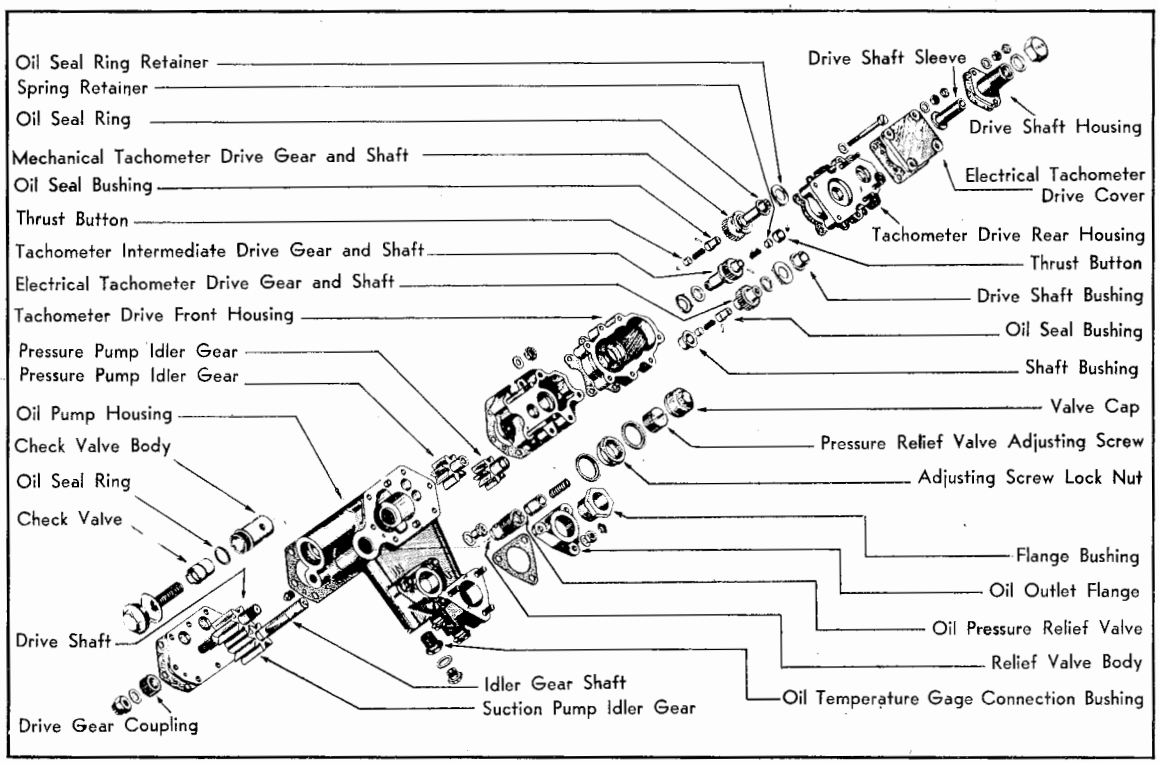



**Fig. 24. Oil Pump Assembly.**

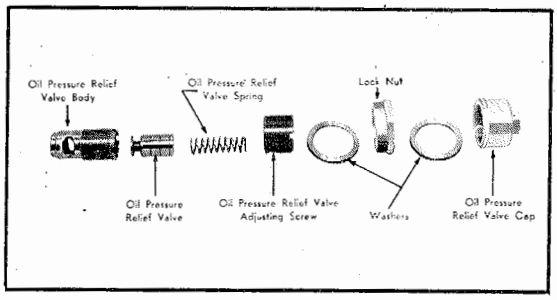

Oil Pressure Relief Valve Body
Oil Pressure Relief Valve Spring
Lock Nut
Oil Pressure Relief Valve
Oil Pressure Relief Valve Adjusting Screw
Washers
Oil Pressure Relief Valve Cap

**Fig. 25. Exploded View Oil Pressure Relief Valve**

justing screw which increases or decreases the tension in the pressure relief valve spring. See figure 25. The pressure pump discharges the oil into a filter inserted into the left side of the supercharger rear section. See figure 26.

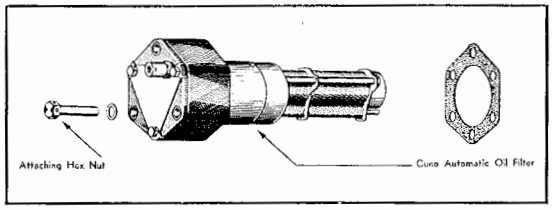



**Fig. 26. Cuno Oil Filter**

The oil is led directly from the filter to an annular groove machined in the accessory drive and starter shaft bushing bore in the rear cover. The rear cover is cast with four ribbed sections extending radially from the accessory drive and starter shaft supporting boss. These sections are drilled to communicate with the annular groove surrounding the accessory drive and starter shaft bushing. A tube conducts oil from the top of this annulus to a pressure gage connection.

The two upper drilled passages supply oil to a groove around the outside circumference of each magneto shaft bushing. The upper portion of each magneto shaft bushing is milled away for the installation of a gun-synchronizer support, uncovering the groove in two locations through which the oil issues to lubricate the gun synchronizer and the inside circumference of the magneto shaft bushing. Provision is made in the gun-synchronizer support for oil drainage back into the rear housing.

The lower right drilled passage provides oil to a groove around the outside circumference of the fuel pump and dual accessory drive-shaft bushing. This bushing is milled away in a similar manner to the magneto bushings to accomodate the fuel pump drive-shaft support, uncovering the oil groove at two points. The oil issuing from these two openings lubricates the inside circumference of the fuel pump and dual accessory drive-shaft bushing. The fuel pump drive-shaft supporting bushings are of sintered material and do not require pressure lubrication. Any oil leakage past the supporting bushings is drained into the supercharger rear housing through holes drilled in the support. A passage is drilled angularly through the supercharger rear housing cover from rear to front at the spare drive mounting pad, communicating with an oil groove opening at the spare drive shaft bushing. Oil under pressure travels through this passage to lubricate the dual accessory drive gear box and the accessories requiring engine oil for lubrication.

The lower left passage is drilled slightly larger than the other because, in addition to conducting the oil to the oil pump shaft bushing, it communicates with other drilled passages to supply oil to the impeller drive, either single-speed or two-speed, and to the generator drive shaft bushing.

Oil from the drilled pressure passage enters the inside of the oil pump shaft bushing through a hole drilled in a groove extending around the outside circumference of the bushing at its front end. A longitudinal groove inside the bushing distributes the oil along its length. A circumferential groove and drilled hole are provided at both ends of the bushing so that it cannot be installed incorrectly.

A ribbed section between the oil pump drive shaft supporting boss and the generator drive shaft supporting boss forms an integral part of the front face of the supercharger rear housing cover casting. A branch passage is drilled through this section intersecting the oil pressure passage to the oil pump drive-shaft bushing. Oil is supplied to a groove in the outside circumference of the generator shaft bushing through this branch passage. The groove is drilled with four holes for lubricating the inside of the bushing. The supercharger rear housing cover is drilled from rear to front at the left side of the generator mounting pad to communicate with the branch oil pressure passage for supplying the generator, or accessory, with engine oil if desired.

On engines equipped with the two-speed plate-type supercharger drive, the control valve assembly, which supplies the oil for the operation and lubrication of the two-speed supercharger drive, receives its supply from a passage drilled in the supercharger rear hous-

ing cover to intersect the pressure oil passage adjacent to the oil pump drive-shaft supporting boss. The oil is distributed from the control valve chamber to the two-speed clutch unit through drilled passages in the supercharger rear housing cover. The valve admits the lubricating oil to a groove in the intermediate impeller drive shaft bushing in the rear cover. The steel portion of the bushing is drilled with longitudinal passages to bring the oil forward to an annulus inside the bushing, where it is distributed by means of a flat on the shaft, and whence it enters the inside of the hollow shaft through a drilled passage. A steel sleeve known as the oil distributor plug is pressed into the hollow shaft to separate the lubricating oil from the operating oil which is used to operate the high-speed ratio clutch. The intermediate impeller drive shaft is drilled to provide lubrication to each of the five pinion gear supporting journals as well as the journals which support the bell-shaped gear and the planetary sun gear. A longitudinal groove through this pressed-in oil distributor plug allows the lubricating oil to reach the front supporting bushing, where it is distributed by a flat in the journal of the impeller drive gear.

Ample drainage facilities are provided to prevent any tendency of the lubricating oil to operate one clutch with the other one engaged. These drainage locations are shown by red arrows on the clutch section of the lubrication chart.

When the roller clutch is used, the lubricating oil for the supercharger clutch drives is supplied from the same annulus around the oil control valve sleeve which supplies the operating oil. Some of the oil flows through a drilled passage from the annulus to the rear end of the intermediate impeller drive shaft rear bushing and through the hollow shaft. At the approximate center of the intermediate impeller drive shaft, some of the oil flows through three drilled passages to lubricate the intermediate impeller drive gear bushing and journal. The remaining oil continues through the hollow shaft and out the propeller end to lubricate the front bushing and journal and the bushing and journal of the impeller drive gear. This oil is also led through drilled passages in the front intermediate impeller drive pinion cage to lubricate the intermediate impeller drive pinions and bushings.

Single-speed engines are equipped with a control valve substituting cover which is provided with oil grooves to connect the supply passage to the intermediate impeller drive gear shaft.

The accessory drive gears run in a continuous spray of oil due to the fact that oil is constantly being forced out of the ends of their shaft supporting bushings. To prevent external oil leakage at the rear end of the generator and magneto drive shafts, the shafts are equipped with spring-loaded oil seals. Instead of spring loading, the accessory drive and starter shaft uses the oil pressure on the starter coupling to effect the seal.

The supercharger rear housing cover is drilled at the base of a recess behind each accessory drive shaft bushing to drain the surplus oil into the supercharger rear housing. The magneto, oil pump, and spare drive shaft recesses have one drain hole each. The generator shaft recess has three drain holes, while the starter and accessory drive shaft recess has two internal drain holes and provision for one external drain on the lower right-hand side of its raised mounting pad.

The oil in the accessory drive and starter shaft bushing is led through holes to the hollow center of the accessory drive and starter shaft. A hole drilled through the shaft leads lubricating oil out to the annulus formed between the accessory drive and starter shaft and the impeller shaft.

From the accessory drive and starter shaft, the oil is led to a recess in the rear crankcheek and from this recess through a drilled passage in the rear crankcheek to the hollow center of the crankpin. The sludge-eliminating oil nozzles lead some of this oil to the master rod bearing. See figure 27. The oil is led from the front end of the master-rod bearing to an annulus in the master-rod bearing end seal and through a series of drilled passages in the knuckle-pin locking plate to the center of each knuckle pin. The knuckle pins each have two drilled holes which lead oil to the knuckle-pin bushings.

Splash lubrication of the pistons and cylinder walls is effected by a crankpin oil meter-

ing screw in the front crankcheek. However, some of the early engines are equipped with a smaller oil jet in the metering screw which is supplemented by another oil jet drilled in the top of the crankpin adjacent to the rear crankcheek. The oil leakage from the knuckle-pin bushings also aids in lubricating the cylinder walls and pistons. Two drilled passages in the rear crankcheek supply oil to the floating damper pin bushings.

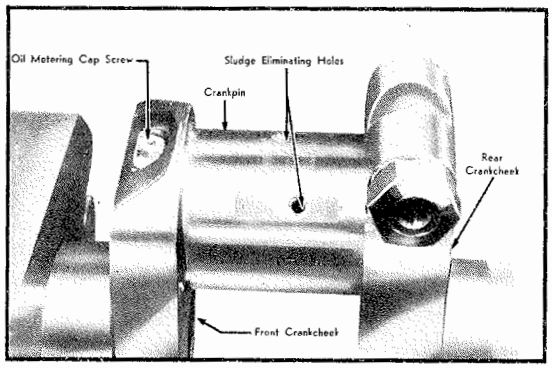



**Fig. 27. Crankshaft Sludge Eliminating Holes and Oil Metering Cap Screws**

A drilled passage in the front crankcheek leads oil from the crankpin to the center of the crankshaft. This hollow shaft acts as a header from which the lubrication passages in the front section are tapped. If a crankshaft breather tube is used in the engine, the rear tube support is so constructed that the oil flows readily into the annulus between the breather tube and the crankshaft, and this annulus serves as the header.

The rear hole in the crankshaft front extension leads oil to an annulus in the inside circumference of the reduction driving gear spacer. The spacer and front main bearing ring are drilled to carry oil to an annulus formed between the front main bearing ring and the inside circumference of the hub on the crankcase front main section. From there, oil is led through drilled holes in the hub and cam bearing ring to the surface of the cam bearing ring. A hole drilled in the cam drive gear bracket communicates with the upper hole in the boss to supply oil to the cam drive gear bushing. Leakage from these bushings lubricates the cam gear teeth.

The remaining hole in the crankshaft leads oil to an annulus formed between the propeller shaft rear bushing and the propeller shaft and to the annulus between the two rear sets of oil seal rings on the thrust bearing spacer. From the annulus in the propeller shaft rear bushing, oil is led to a hole drilled in each of the six spider arms on the 3:2 ratio propeller shaft. The oil is fed through these passages into a groove in each spider arm bushing. From these grooves the oil passes through drilled holes in the pinions into the annulus formed between the inside of the pinion and the pinion lock nut. Another drilled hole leads oil from this annulus back to the bushing in the spider arm. Leakage from the bushings lubricates the reduction driving gear teeth.

The 16:9 ratio propeller shaft employs a slightly different system. The flanged end of the propeller shaft has eight drilled passages leading from the supply groove in the propeller shaft rear bushing to the annulus formed between the flange and the trunnion carrier ring. Drilled passages in the carrier ring connect the center of each trunnion to this annulus. The pinion lock bolts have a reduced section in the center, forming an annulus between the bolt and the trunnion inside circumference. Two drilled holes in the trunnions convey oil to the inside of the bushing. Leakage from the bushings lubricates the reduction driving gear teeth. A small hole is drilled through the propeller shaft flange from front to rear, connecting with the carrier ring annulus. This hole supplies a constant spray of oil to the stationary reduction gear teeth.

The oil, which was described as being led to the annulus between the two rear sets of oil seal rings on the thrust bearing spacer, is conducted through drilled passages in the stationary reduction gear support and the front section to the governor mounting pad. This is the low, or engine, pressure governor oil line and is shown as the lower passage on the lubrication diagram. This line serves both the governor pump and the tappet and rocker arm assemblies. The tappets and rocker arms will be considered first.

The oil is discharged to an annulus surrounding the governor drive shaft bushing. It lubricates this bushing, and is led from the annulus through a drilled passage to connect

with the channel machined into the shoulder on the rear face of the crankcase front section. This channel is sealed by the rubber oil seal ring of T-cross-section between the crankcase front section and the crankcase front main section. From it, drilled passages lead to the eight tappets which are located above the horizontal center line of the engine. Mating holes in the tappets and guides lead the oil to the inside of the tappets. From here it is forced through the hollow push rods to the rocker arms. The rocker arms are also drilled, and the oil is forced to the rocker arm bearings under pressure. Oil escaping from the bearings lubricates the valve stems. Return oil flows down the space between the push rods and push rod housings, through holes in the tappet guides, and then back into the front section, lubricating the tappet roller and cam surface.

Tappets, rocker-arm bearings, and valves below the horizontal center line are lubricated by crankcase oil seeping through the clearance between each valve tappet and its guide, after which it passes through the inside of the push rod housing and fills the rocker box. The desired quantity of gravity-fed oil for this purpose is obtained by controlling the valve tappet diametric clearance in their guides.

When a governor is used, the governor takes oil from the low pressure line and increases its pressure to that required for propeller operation. This high pressure oil is returned to the propeller shaft through drilled passages in the front section and stationary reduction gear support to the passage between the two forward sets of rings in the thrust bearing spacer.

From the forward space in the thrust bearing spacer, the high pressure oil is led through a hole in the propeller shaft to the annulus between the propeller shaft and the propeller shaft sleeve. From here it is taken through the adapter to the hydromatic propeller. This passage is sealed at the adapter if an electric propeller is used.

All return oil drains to the sump. See figure 28. The power section oil drains from the bottom of the crankcase main section through two short tubes into the front section, where it joins the front section drainage, and passes into the sump through the front section connection. The power section oil also drains from the rear of the crankcase main section into a cored passage in the supercharger front section, joining the drain oil from the accessory drive section. Oil from the accessory drive section or supercharger rear housing, drains

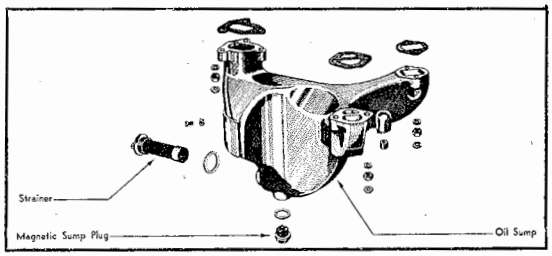



**Fig. 28. Oil Sump**

through cored passages in the supercharger front and rear housings and through the left hole in the left arm of the sump. Front section flow and rear section flow may be diverted for test purposes to obtain an accurate measurement of oil flow from the power section alone.

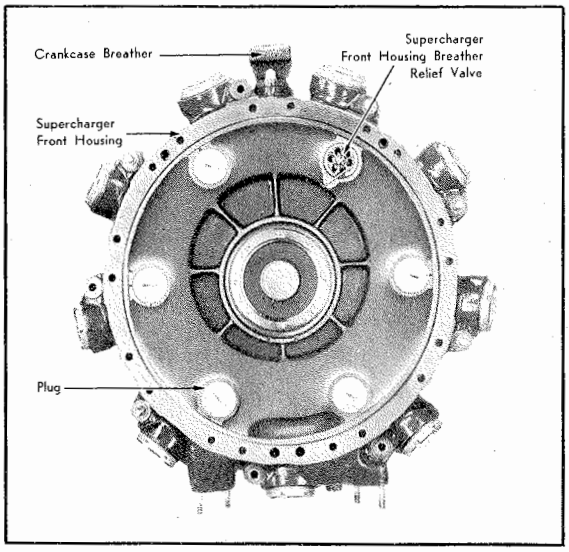



**Fig. 29. Location of Supercharger Front Housing Breather Relief Valve**

Breathing takes place through the sump connections to the right arm of the sump. This arm connects through a boss on the supercharger front section to a large passage leading to the breather vent outlet. Some engines

use a crankshaft breather in place of this external breather. Of the six cored holes in the supercharger front section breather passage, all are plugged but one which is equipped with a breather relief valve. Its purpose is to provide a more direct outlet for any gases that create excessive pressure in the power section. See figure 29.

Oil is withdrawn from the sump through the left of the two holes in the left arm of the sump. External oil scavenge lines are supplied with some engines. The external oil line is connected to an adapter at the front of the sump oil strainer and is routed close to the engine crankcase to a vertical or horizontal scavenge oil inlet at the oil pump. The tube is clamped to the engine at several locations to prevent vibration. See figure 30.

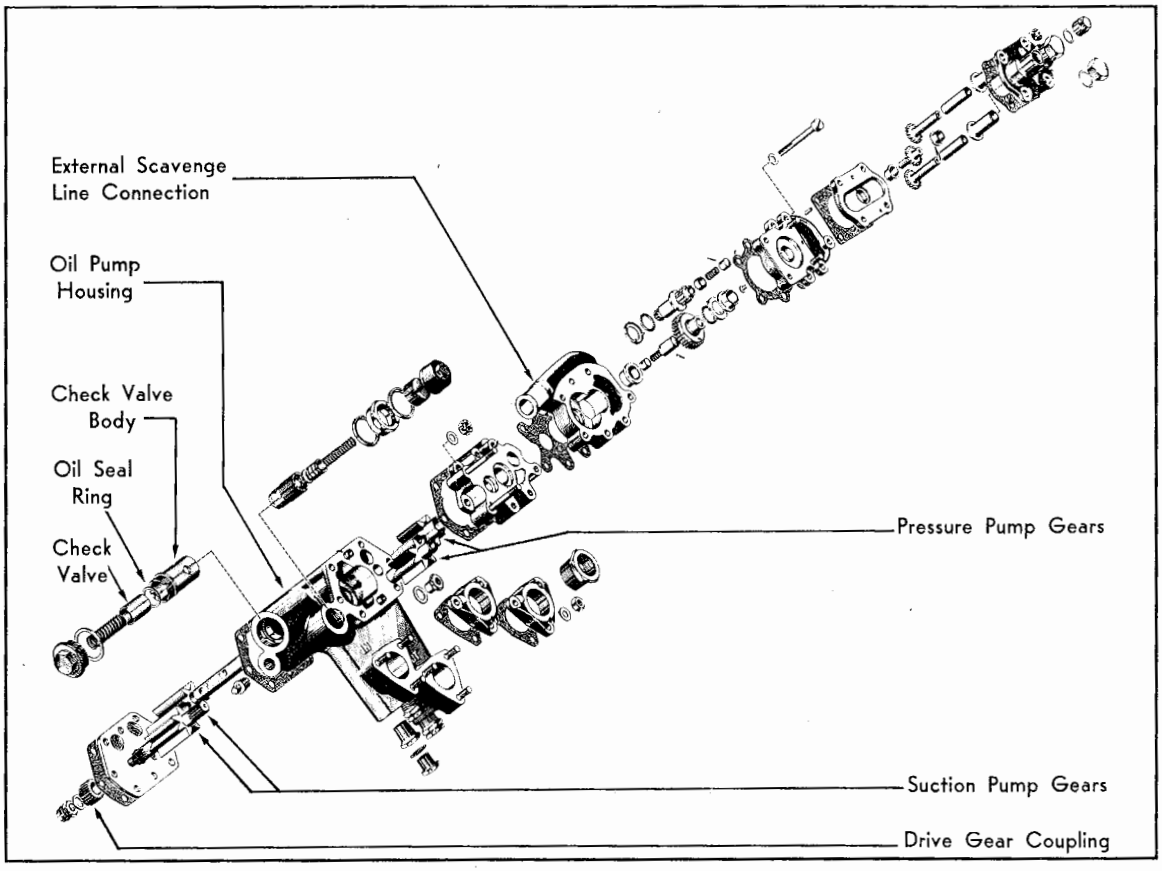



**Fig. 30. Oil Pump Assembly With Provision for External Oil Scavenge Line**

**CARBURETION** The series C9GC engines are equipped with either a Holley, Bendix Stromberg, or Chandler Evans carburetor.

The Holley carburetor has a single air passage controlled by a variable venturi. Fuel is admitted to a supply chamber by a diaphragm mechanism. A controlled pressure differential produced by the variable venturi causes fuel to flow from the supply chamber to the metering nozzle located in the venturi throat. The fuel discharge nozzle and venturi throttles are arranged in such a manner that the carburetor is inherently free of ordinary icing troubles. Also the type of fuel metering system and throttle used in this carburetor provide partial compensation for changes in altitude. More exact altitude adjustment and increased economy under favorable operating conditions are obtained by means of a manual control which is provided for leaning out the fuel air ratio.

The Holley carburetor is also provided with a fuel cut-off device which is brought into action by moving the mixture control to the "FULL LEAN POSITION."

The accelerating pump on the Holley carburetor functions only when the engine is running. Consequently, opening or closing the throttle prior to starting will not flood or prime the engine. A charge of fuel is retained by the accelerating pump for approximately two hours after the engine is stopped if the mixture control is left in the "CUT-OFF" position. Movement of the mixture control to the full rich position when cranking the engine will permit the use of this charge to assist in restarting.

The Bendix Stromberg Injection carburetor employs the method of metering the fuel through fixed orifices according to the venturi suction, combined with the function of atomizing the fuel spray under positive pump pressure. This carburetor is inherently ice-free as the fuel is injected below the throttle venturis.

The fuel enters the metering system at a pressure above that in the supply tank. The fuel is delivered by the engine fuel pump into the regulator and control units where it is metered according to the mass air flow rate, as registered by the venturi tube and aneroid system of the throttle unit. The fuel is then forced to the discharge nozzle, located to spray the charge evenly across the supercharger entrance.

The control unit contains a cruise metering jet which can be modified to rich cruise and lean cruise by the manual control, also a take-off metering jet which is brought in gradually according to engine horsepower increase, as measured by mass air-flow rate.

Both cruising and full power mixture ratios are kept constant under temperature and altitude change by the automatic mixture control unit.

The Bendix Stromberg Injection carburetor is also provided with a fuel cut-off device which is brought into action by moving the mixture control to the "CUT-OFF" position.

The Chandler Evans carburetor is similar to the Holley in construction and the Holley operating instructions apply to it without change.

**IGNITION** Ignition is furnished by two Scintilla magnetos mounted on the rear cover. See figure 31. The right magneto fires the front spark plugs, and the left magneto fires the rear spark plugs. Both magnetos rotate at 1⅛ crankshaft speed in the direction of crankshaft rotation. The spark advance to be used is stamped on the engine data plate. The magnetos may be equipped with blast covers and tubes to aid in directing cooling air to the magneto housing. Magnetos are compensated for equal spark advance on all cylinders.

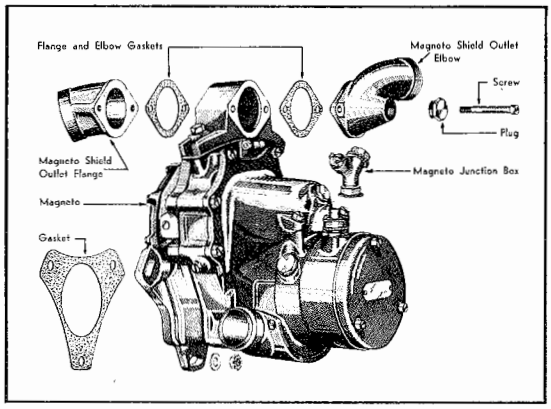



**Fig. 31. Magneto**

The wire, enclosed in bronze or stainless-steel cables, is rubber-insulated and coated with a protective compound to prevent wear and deterioration. The manifold consists of two semi-circular rings of stainless steel or cadmium-plated brass tubing. These tubes are attached to the front section cap screws and carry the ignition wires for their respective sides of the engine. Clips on the push-rod housings and cylinder-head deflectors prevent the ignition leads from rubbing against the engine. Terminal assemblies are provided at the end of the front and rear of the ignition leads, forming a very compact and efficient connection at the spark plug.

All parts of the ignition system are shielded against radio interference. The shielding is constructed so that any part, if damaged, may be readily replaced without discarding the entire shielding structure. Any defective ignition wire may likewise be replaced without disturbing other wires. See figure 32.

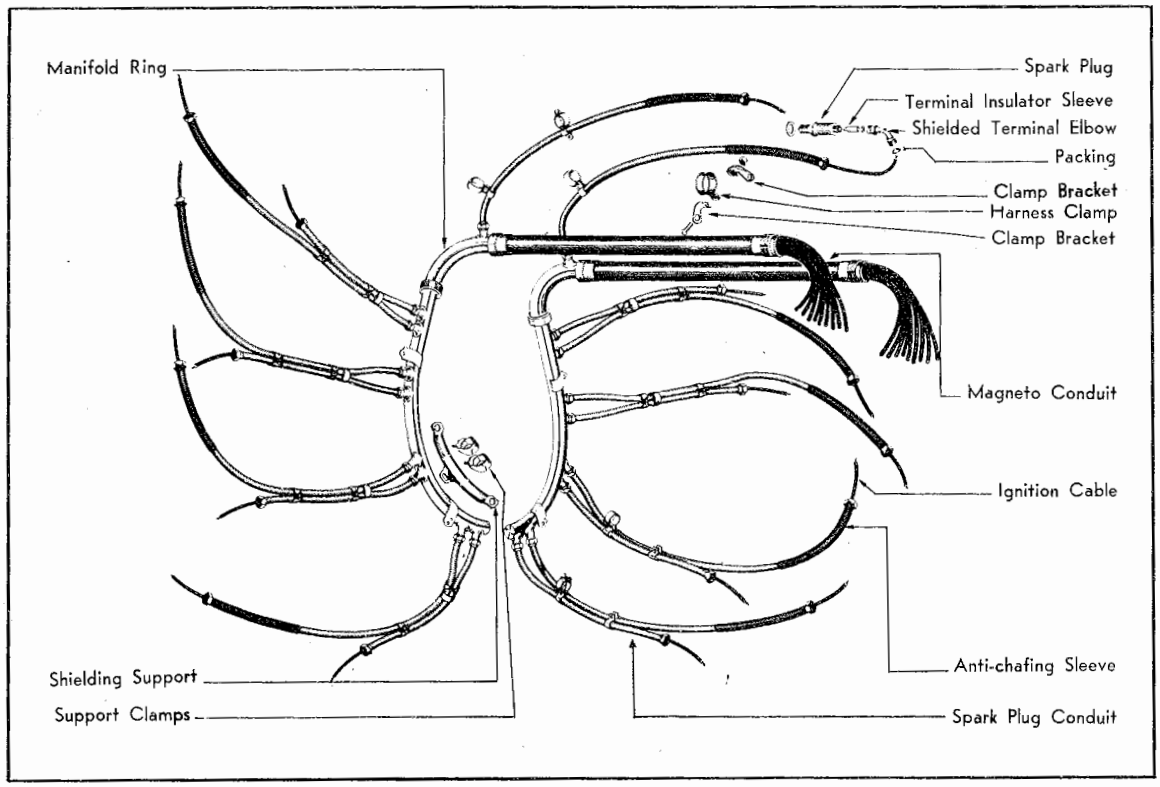



**Fig. 32. Ignition Harness**

**GENERATOR DRIVE** The rear cover of the C9GC engine is provided with a pad suitable for attachment of a generator with a six-bolt round mounting flange. The drive shaft rotates at 1.5 times crankshaft speed and in the same direction as the crankshaft. It is machined to receive a generator shaft with sixteen involute splines. See figure 33.

**TACHOMETER DRIVES** Provision is made at the rear end of the oil pump for two tachometer drives, one electrical and one mechanical. The tachometer drives are effected by a small drive shaft which is splined at one end to mate with similar splines in the pressure oil pump drive shaft. Oil leakage is prevented by the use of spring-loaded plungers and neoprene ring oil

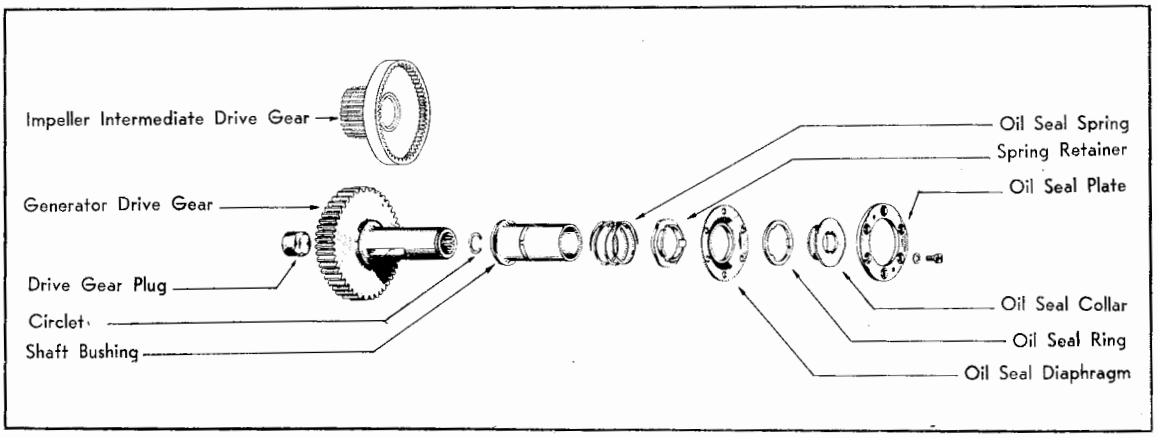



**Fig. 33. Generator Drive**

seals. The extended type is the mechanical tachometer and the flange type is the electrical. Both the tachometer drives have the same speed ratio and rotate in a clockwise direction.

Oil pumps incorporating an external oil scavenge line are equipped with only the electrical tachometer drive. However, an alternate arrangement is provided whereby two mechanical tachometer drives replace the electrical drive. An adapter, a pinion, two mechanical tachometer drive shafts, and a dual tachometer drive housing are assembled on the electric tachometer drive pad to form the alternate arrangement. The drive is effected by the pinion which has a square tongue drive in the electric tachometer drive gear and which meshes with the gears at the end of each mechanical tachometer drive shaft.

**DUAL ACCESSORY DRIVE** Provision for optional accessory drives is made possible by the use of a spur gear box attached to the supercharger rear housing cover at the spare drive mounting pad. The gear box body is composed of a magnesium-alloy casting, studded for the attachment of an aluminum-alloy cover plate. The bushings which support the gears are located in the cover plate and in the body of the gear box. The main drive gear is machined integral with the shaft that extends through the upper left-hand corner of the housing wall to mate with the spare drive gear shaft in the supercharger rear housing cover. This main drive gear meshes with an intermediate gear near the center of the housing to make up the primary or first gear train of the unit. The secondary train of gears, identified by their smaller teeth, consists of a secondary driving gear which is bolted to the primary intermediate gear, and two accessory drive gears. To change the speed ratio of the accessory drives to the crankshaft, it is only necessary to replace the two gears in the primary gear train. All the gears are machined from alloyed steel forgings. The lower acces-

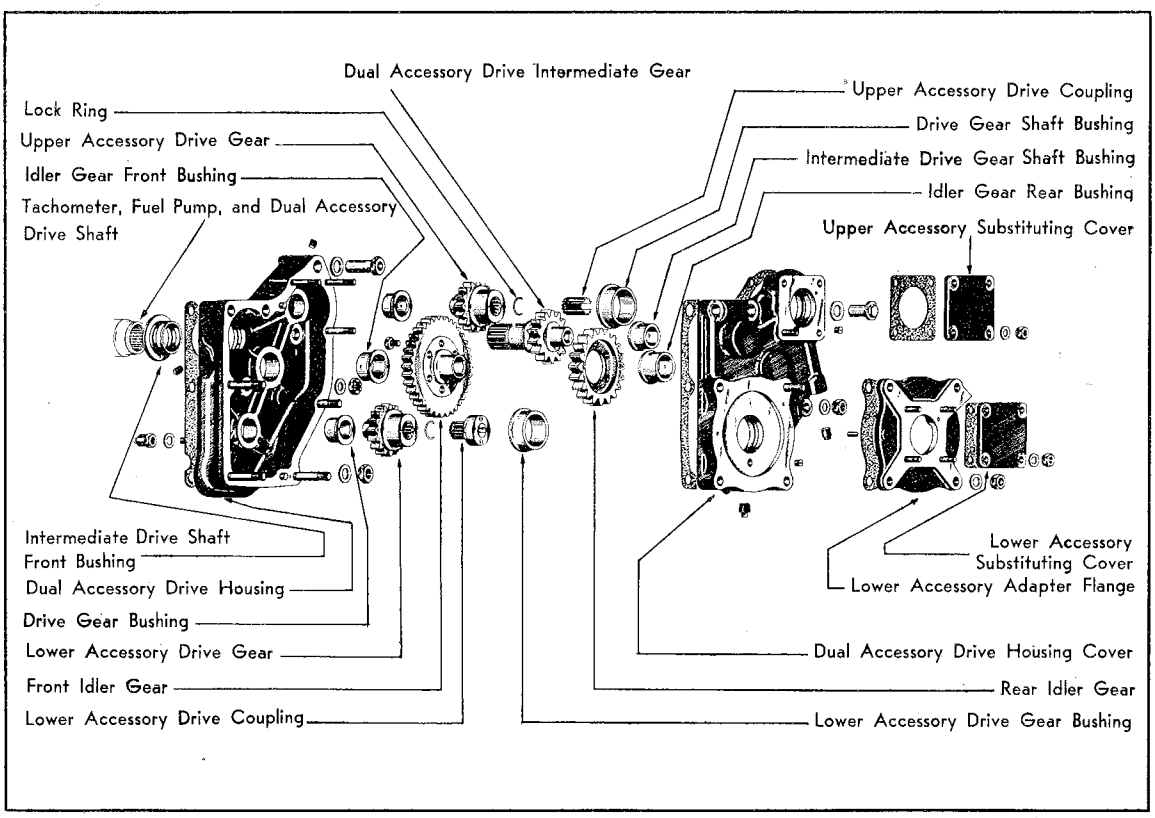

Dual Accessory Drive Intermediate Gear
Lock Ring
Upper Accessory Drive Gear
Idler Gear Front Bushing
Tachometer, Fuel Pump, and Dual Accessory Drive Shaft
Upper Accessory Drive Coupling
Drive Gear Shaft Bushing
Intermediate Drive Gear Shaft Bushing
Idler Gear Rear Bushing
Upper Accessory Substituting Cover
Intermediate Drive Shaft Front Bushing
Dual Accessory Drive Housing
Drive Gear Bushing
Lower Accessory Drive Gear
Front Idler Gear
Lower Accessory Drive Coupling
Lower Accessory Substituting Cover
Lower Accessory Adapter Flange
Dual Accessory Drive Housing Cover
Rear Idler Gear
Lower Accessory Drive Gear Bushing

**Fig. 34. Dual Accessory Drive Mechanism**

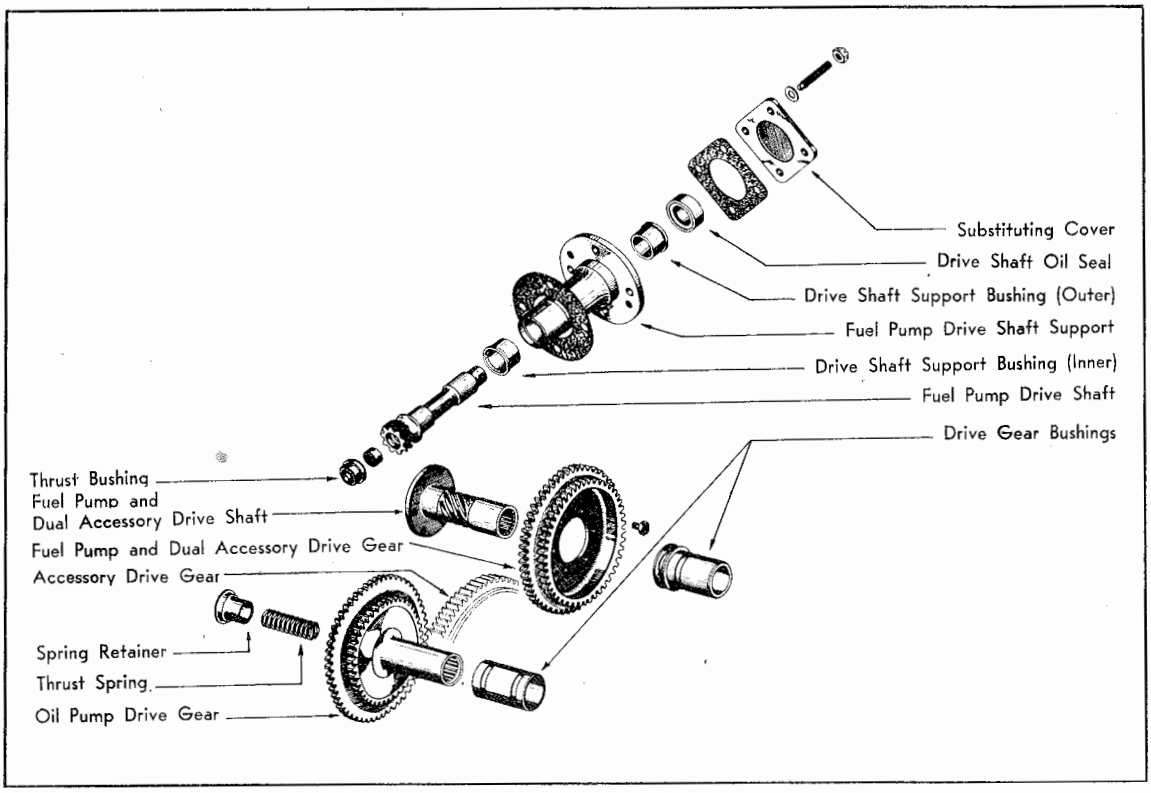



**Fig. 35. Fuel Pump Drive**

sory drive is supported by two sintered bushings while the upper drive is supported by a sintered bushing in the cover and a bronze bushing in the housing. All the other drives in the unit are supported by bronze bushings. Both the housing and cover of the unit are drilled for oil passages. Provisions are made for the conversion of the splined drives to the tongue-type drive by the addition of steel couplings. An adapter equipped with drilled oil passages may be installed on the lower drive pad if it is desired to mount an accessory with a smaller mounting pad. See figure 34.

**FUEL PUMP DRIVE** Provision is made for mounting a fuel pump on the right side of the supercharger rear housing. The mounting pad is circular and is fitted with 12 tapped holes equally spaced. The round pad on the shaft support is drilled with four stud holes. With this arrangement, the fuel pump may be installed in any one of 12 positions. See figure 35.

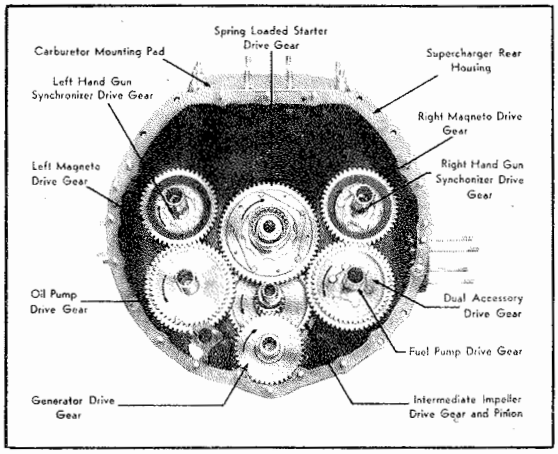

Spring Loaded Starter Drive Gear
Carburetor Mounting Pad
Supercharger Rear Housing
Left Hand Gun Synchronizer Drive Gear
Right Magneto Drive Gear
Left Magneto Drive Gear
Right Hand Gun Synchonizer Drive Gear
Oil Pump Drive Gear
Dual Accessory Drive Gear
Fuel Pump Drive Gear
Generator Drive Gear
Intermediate Impeller Drive Gear and Pinion

**Fig. 36. Location and Direction of Rotation of Accessory Drive Gears**

## CHAPTER II

# DISASSEMBLY OF ENGINE

**REMOVING ENGINE FROM SHIPPING BOX** Break the seals and remove the four bolts from the metal straps on the shipping box.

Attach a hoisting cable to the hooks on the metal straps and remove the shipping box cover. See figure 37.

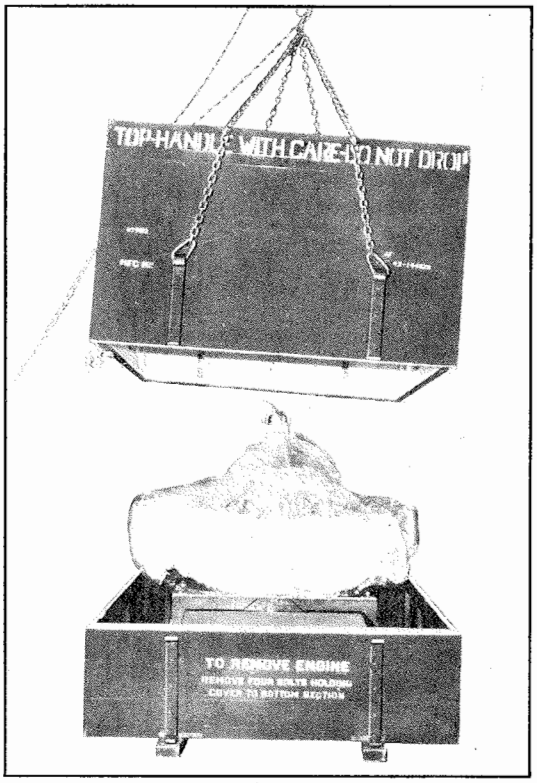



**Fig. 37. Raising Shipping Box Cover**

Slit the plastic-film envelope along the top seam and roll the envelope down over itself to the engine mounting plate. Since the envelope may be used several times (as many as six), care should be taken in opening and removing it. If possible, the temperature at which plastic film is handled should be 70 deg. F or higher.

Remove all the dehydrating bags from the cylinders and remove the humidity indicator.

Remove the thread-protecting cap and install the engine hoisting eye. Attach the hoist to the eye.

Remove the nuts which secure the mounting plate to the cradle.

Raise the engine and mounting plate from the shipping box. See figure 38.

**Fig. 38. Removing Engine from Shipping Box**

Remove the mounting plate and the plastic-film envelope from the engine. See figure 39.

Remove the oil tank vent sump from the rear cover.

**REMOVING ENGINE FROM AIRPLANE** The following instructions should be observed, in close connection with instructions provided by the aircraft manufacturer for the particular airplane concerned, when removing a Cyclone 9GC engine from an airplane:

Install the propeller-shaft thread protector (Tool No. 83922) over the propeller shaft threads after removing the propeller hub nut. Remove the propeller and all propeller attaching parts. Remove the protector. Screw the hoisting eye (Tool No. 83761) on the propeller hub nut threads on the propeller shaft.

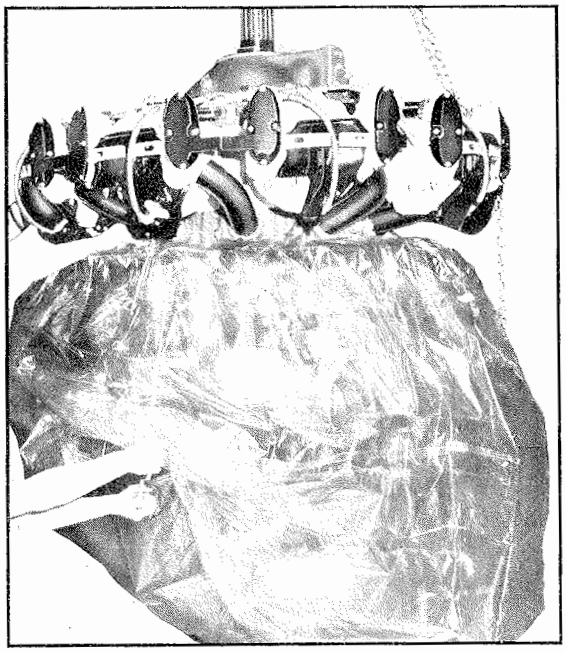


**Fig. 39. Removing Mounting Plate**

Remove the carburetor air scoop and as much of the engine cowling as is necessary in order to attach the engine hoisting sling to the engine. Reinstall the air scoop attaching nuts and washers on the carburetor studs. Attach the engine hoisting sling (Tool No. 84329) to the engine as follows: Secure the metal straps of the sling to the cowl attaching studs at the front and rear of the intake rocker boxes of cylinders No. 1 and 9, using eight lock washers and nuts. The wire cable is designed so that the bent seamless steel tubing on the cable, around which the hoisting hook is passed, is located directly above the center of gravity of the engine. Care must therefore be taken to insure that the metal sling straps are attached to the proper rocker boxes so that the engine will be properly supported when hoisting. Insert the spreader bar between the two arms of the cable assembly, and tighten the cable clamps before hoisting. See figure 40 for a view of the engine hoisting sling in position.

Disconnect all controls, gage lines, fuel and oil lines, tachometer, and electric connections. Remove the engine mount attaching bolts at the engine or at the firewall, whichever is more convenient or desirable. Pass the hook on a chain hoist around the engine hoisting sling, and lower the engine out of the airplane. If the engine mount is not removed from the engine before removal of the engine from the airplane, it may be desirable to loop additional cables around the hoisting hook, attaching the cables to other points on the engine mount.

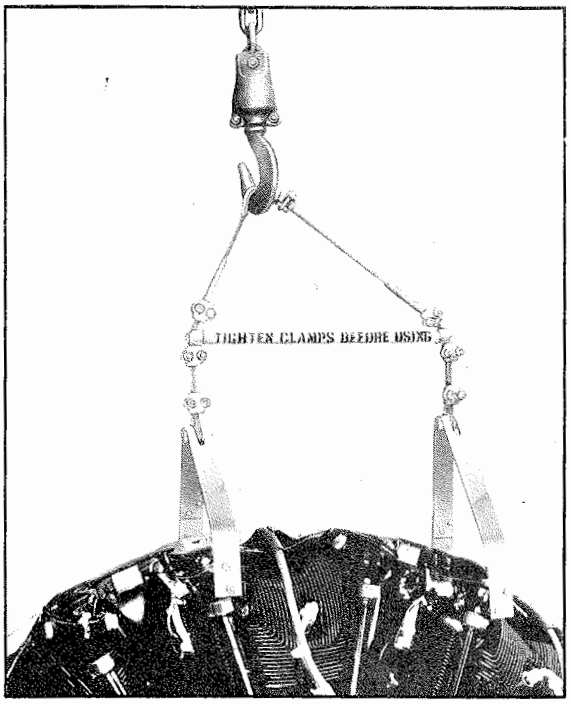



**Fig. 40. Hoisting Engine Using Rocker Box Sling**

Lower the engine to a convenient height for accessibility. Remove the exhaust manifold and all cowling remaining on the engine. If the engine mount is attached to the engine, remove the mount after removing the carburetor, fuel pump, gun synchronizers, magnetos, or any accessories which may impede the removal of the mount structure. Instructions for the removal of accessories are included in

the chapter entitled DISASSEMBLY OF ENGINE, under the subtitles SPARK PLUGS, CARBURETOR, ACCESSORIES.

Mount the engine on a disassembly stand as described in the chapter entitled DISASSEMBLY OF ENGINE.

No less than two men should ever attempt to remove an engine from an airplane. Two men are necessary to perform this operation safely in order that one man can guide the engine while a second man handles the hoist.

Close cooperation between hangar personnel and the engine overhaul shop is required to eliminate unnecessary labor, expense, and confusion. The hangar personnel should be instructed to include with each engine which is to be overhauled, all parts and accessories which will require overhaul or which are necessary for testing purposes. It is desirable that the following parts be kept with the engine, either attached or unattached:

1. Carburetor and Adapter
2. Throttle and Mixture Control Arms
3. Magnetos
4. Starter
5. Fuel Pump
6. Cuno Oil Filter
7. Gun Synchronizers (if used)
8. Electric Tachometer (if used)
9. Propeller Governor (if used)
10. Spark Plugs
11. Ignition Wiring Manifold Assembly

Unless an accurate record is kept in the overhaul shop of the equipment received on or with the engine, confusion may result, following the overhaul of the engine, regarding missing parts or accessories. To avoid the possibility of confusion, it is recommended that a form similar to the ENGINE RECEIVING INSPECTION REPORT, included in the section of the Appendix entitled SERVICE STATION MANAGEMENT AND ROUTINE FORMS, be used. This form may be varied to suit the particular organization under which the engine overhaul shop functions.

If the engine is not to be overhauled immediately, prepare it for storage by slushing. Instructions covering the slushing of engines are included in the chapter entitled PREPARATION OF ENGINE FOR STORAGE.

**MOUNTING ENGINE ON DISASSEMBLY STAND** Insert the hook on the chain hoist through the engine hoisting eye (Tool No. 83761), which is installed on the propeller shaft. Lift the engine by means of a suitable chain hoist of not less than one ton (910 kg.) capacity until it is suspended in a front end up position. If an engine hoisting sling is attached to the intake rocker box studs on cylinders No. 1 and 9, remove the sling.

Move a revolving cradle type engine assembly and disassembly stand (consisting of base, Tool No. 83678, and mounting plate, Tool No. 83679) directly under the engine. Turn the mounting plate to receive the engine in a front end up position, and lock the mounting plate in that position. Lower the engine onto the stand so that the carburetor is located in the center of the cutaway portion of the mounting plate. See figure 41. Attach the engine securely to the mounting plate using five nuts and bolts through the mounting lug

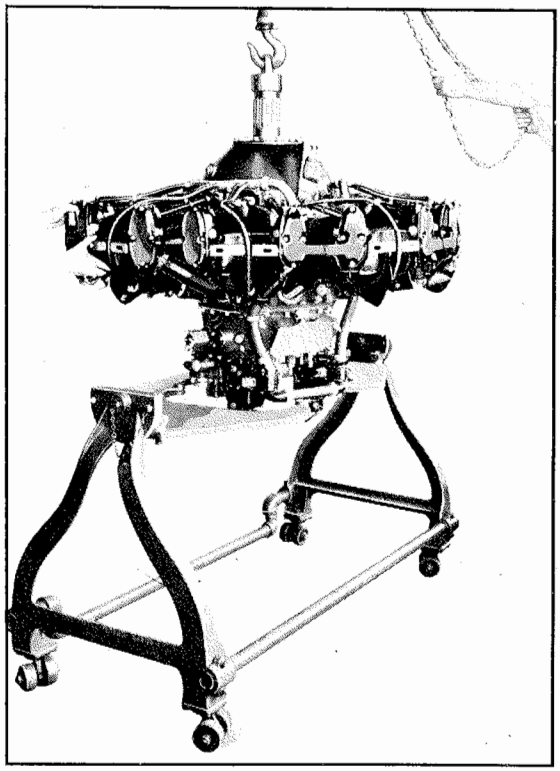


**Fig. 41. Mounting Engine on Disassembly Stand**

holes in the supercharger front housing. Remove the hoist and hoisting eye.

Turn the mounting plate until the engine is in the normal flight position, and lock the mounting plate in this position.

Place the propeller shaft thrust bearing nut lug wrench (Tool No. 82889) over the propeller shaft, and loosen the thrust bearing nut one or two turns by striking heavily on one end of the wrench using a lead hammer. See figure 42. It is desirable to loosen the thrust nut at this time since the nut is ordinarily so tight on the propeller shaft that difficulty will be experienced in loosening the nut after removal of the crankcase front section.

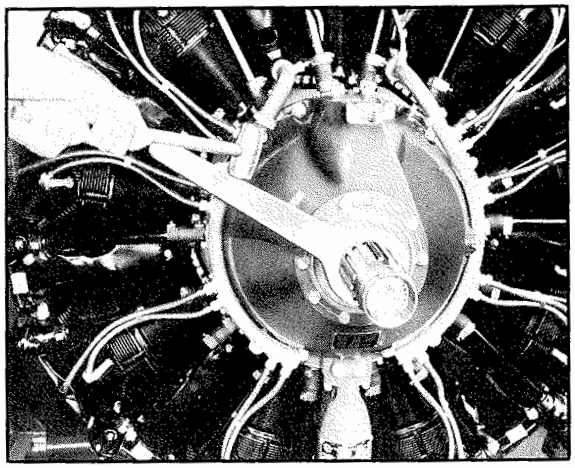


**Fig. 42. Loosening Thrust Bearing Nut**

# SPARK PLUGS, CARBURETOR, ACCESSORIES, INTAKE PIPES, AIR DEFLECTORS, OIL SUMP

**SPARK PLUGS** Loosen the spark plug terminal elbow coupling nut from all spark plugs. Withdraw the elbows from all spark plugs, and remove the plugs. Use spark plug wrench (Tool No. 84450) for ⅞ inch (22.23mm) hexagon spark plugs and wrench (Tool No. 84414) for 1 inch (25.40mm) hexagon plugs. See figure 43. Place the spark

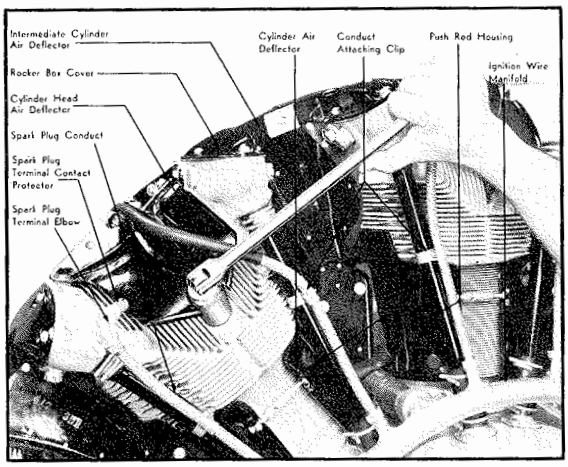



**Fig. 43. Removing Spark Plugs**

plugs in a board having drilled holes to accommodate the electrode end of the plug. Install vented dummy plugs in the spark plug holes in all cylinders. Install a cover (Tool No. 800910) over the exhaust port in all cylinders.

**PRIMING SYSTEM** Two systems of engine priming are commonly employed. In one system, the priming charge is directed into the carburetor adapter. See figure 44. In the other system, the priming

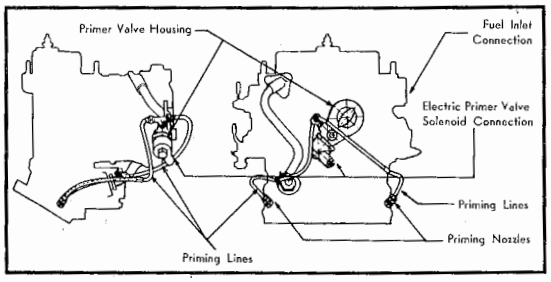



**Fig. 44. Two Point Priming**

charge is directed into the intake ports of the upper five cylinders. See figure 45.

On engines which are primed through the carburetor adapter, remove the priming lines and their attaching brackets, the priming nozzles, priming distributor, all hoses and tubing to the distributor from the carburetor and solenoid, the solenoid and the electrical junction box and conduits. Tag all priming lines, hoses, and tubing to insure that they will be installed in their original positions on the engine after the engine is reassembled.

On engines which are primed through the

intake ports of the upper five cylinders, unscrew the union nuts from the priming tube fittings in the intake ports of the upper five cylinders and from the nipples on the priming distributor. Remove the nuts, washers, and bolts which attach the priming tube clamps to the intake pipes, and remove the priming

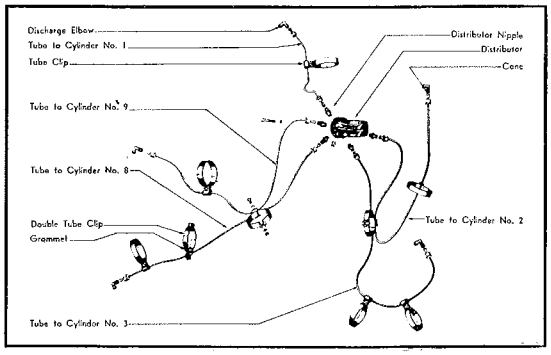



**Fig. 45. Five Point Priming**

tubes. Tag all priming tubes so that they will be installed in their original position on the engine after the engine is reassembled. Detach the priming system supply line from the distributor.

**OIL DILUTION SYSTEM** If an oil dilution system is used, disconnet the oil dilution valve from the oil inlet line to the engine oil pump and disconnect the oil dilution supply line from the carburetor. Remove the oil dilution supply line and valve.

**BENDIX STOMBERG CARBURETOR** Remove the ten palnuts, nuts, and washers from the carburetor air scoop attaching studs. Remove the carburetor air inlet screen and two gaskets.

Remove the eight cotter pins, castellated nuts, and sperical seat washers which attach the carburetor to the supercharger rear housing. Remove the carburetor and gasket. Cover the opening to the induction passage in the rear housing with a suitable plate drilled to pass over the carburetor adapter studs.

**HOLLEY CARBURETOR** Remove the eight palnuts, nuts, and washers from the carburetor air scoop attaching studs. Remove the carburetor air inlet screen, the air scoop adapter, and the three gaskets.

Remove the six palnuts, nuts, and spherical seat washers under the rim of the carburetor adapter flange, which attach the carburetor to the adapter. Remove the carburetor and gasket.

Remove the two acorn nuts and spherical seat washers and six palnuts, nuts, and spherical seat washers which attach the carburetor adapter to the supercharger rear housing. Remove the adapter and gasket. Cover the opening to the induction passage in the rear housing with a suitable plate drilled to pass over the carburetor adapter studs.

**ACCESSORIES** Remove the vacuum pump, electric tachometer, and other spare drive accessories, if used, from their respective mounting pads. Remove the generator. Open end wrench (Tool No. 801080) is designed to provide accessibility to the generator attaching nuts. Remove the starter. Box wrench (Tool No. 801081) and open end wrench (Tool No. 84654) are designed to provide accessibility to the starter attaching nuts. Remove the two magnetos in accordance with the following instructions: Remove the six cap screws and lock washers which secure the coil cover to the front end of each magneto, passing through the radio shield assembly. Remove the two cap screws which secure the coil cover to the housing of each magneto at the breaker end of the housing. Lift off the coil covers. Pull the radio shield assembly of each magneto, in which the distributor block

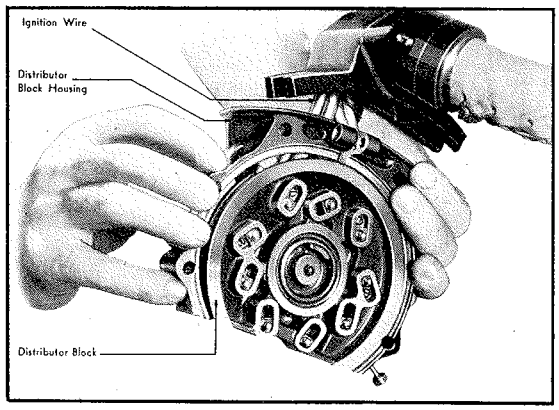



**Fig. 46. Removing Magneto Block Housing**

is housed, back toward the coil to disengage it from the front end plate of each magneto, and then lift the radio shield assemblies away from the magnetos. See figure 46. Remove

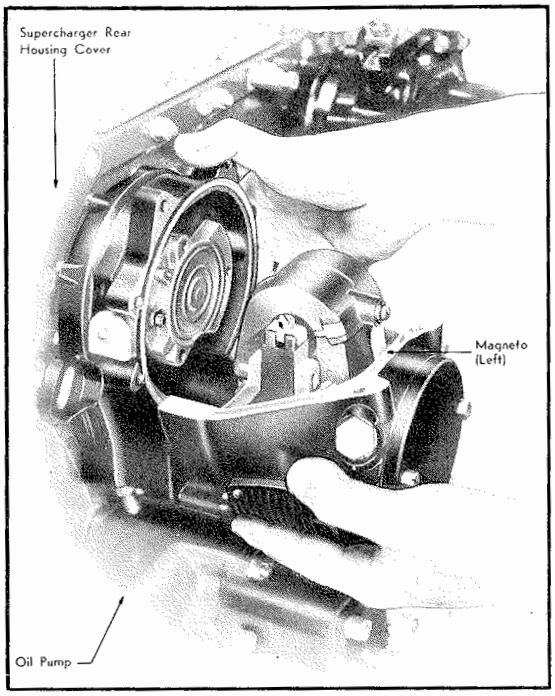



**Fig. 47. Removing Magneto**

both magnetos. See figure 47. The radio shield assembly and distributor block of each magneto and the cross-over conduit attached to the two radio shield assemblies will remain attached to the ignition wiring manifold.

Remove the fuel pump from its mounting pad on the supercharger rear housing.

Remove the propeller governor, if used, from the crankcase front section.

**INTAKE PIPES** Loosen the packing nut at the crankcase end of all intake pipes using the lug wrench (Tool No. 84258). See figure 48. Remove the three cap screws and shakeproof lock washers at the cylinder end of all intake pipes. Pull the flange back from the intake port on each intake pipe. Discard the gaskets and packing. Withdraw the intake pipes from the supercharger front housing.

Install a cover (Tool No. 800909) over the intake port of all cylinders, and install a cover (Tool No. 800907) in all intake pipe

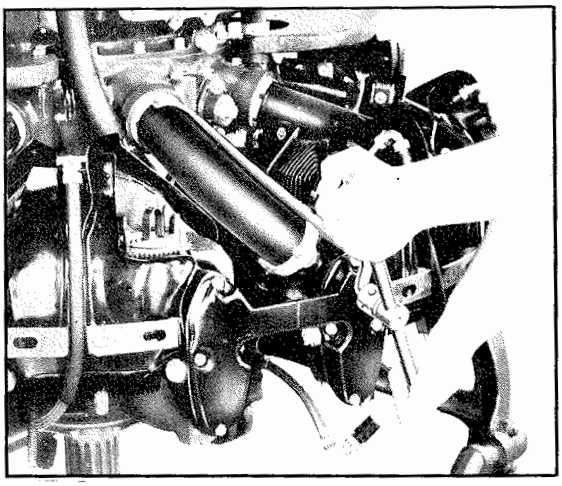


**Fig. 48. Loosening Intake Pipe Packing Nut**

packing nuts in the supercharger front housing. See figures 49 and 50.

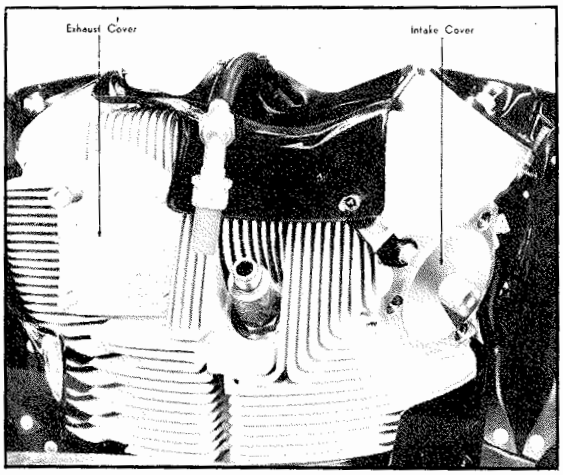



**Fig. 49. Location of Intake and Exhaust Covers**

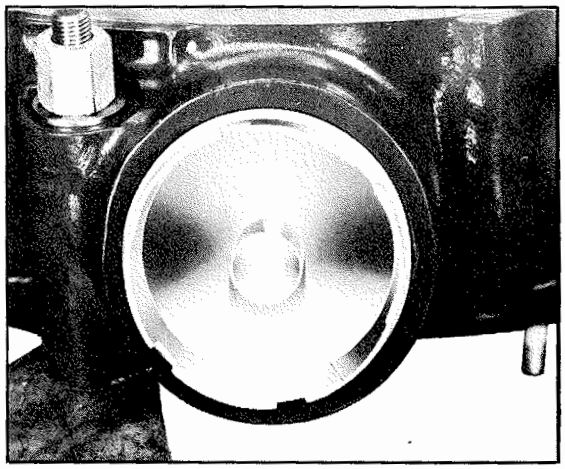


**Fig. 50. Intake Pipe Packing Nut Cover Location**

**AIR DEFLECTORS** Withdraw the rear spark plug conduits from the channel section in each cylinder-head air deflector. Break the lock wire from the fillister head screw attaching each cylinder-head air deflector at the cylinder intake port, and remove these screws. Break the lock wire from the two fillister head screws at the top of each deflector and remove these screws. The cross member of the deflector is slotted to permit easy access to these screws with a screwdriver. Remove the cylinder-head air deflectors. Place deflectors in a large container. See figure 51.

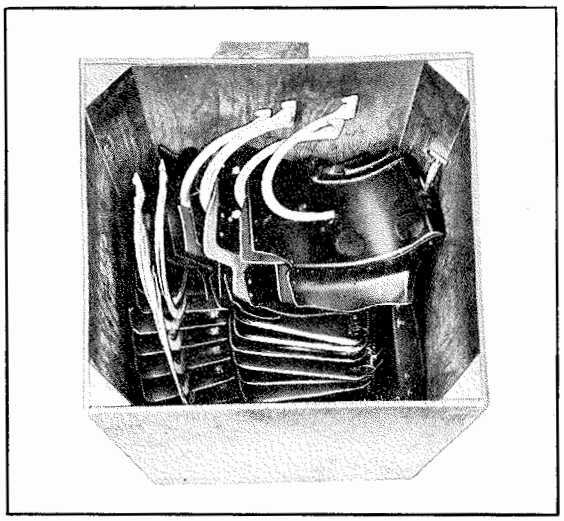


**Fig. 51. Air Deflectors in Container**

Remove the nut from the through bolts which secure the intercylinder air deflector clamps. Remove the clamps, bolts, and spacers, and reassemble these parts after removal to prevent loss. Remove the nuts, plates, and grommets from the studs which attach the deflecors to the rocker box cover extensions. Remove the intercylinder air deflectors from the rear. Reinstall the plates and rubber grommets to the stud on the deflectors to prevent loss of these parts.

The instructions in the previous paragraph apply to all intercylinder air deflectors except the one located at the sump section. To remove this intercylinder air deflector, remove the nut, plate, and grommet which secure the deflector to the rocker box cover extensions. Break the lock wire and remove the two cap screws which attach the deflector to the arms of the sump. Withdraw the deflector to the rear.

**OIL SUMP** Remove the magnetic drain plug from the bottom of the sump. Drain the oil from the sump if this has not already been done. Remove the screened sump plug using wrench (Tool No. 82058). See figure 52.

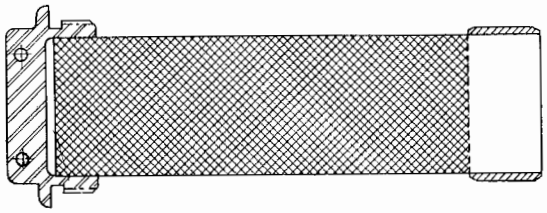


**Fig. 52. Screen Type Sump Plug**

Remove the three palnuts, nuts, and washers which secure the front sump attaching flange to the crankcase front section. Hold the sump and remove the two palnuts, nuts, and washers which attach each arm of the sump to the supercharger front housing. Remove the sump.

## IGNITION WIRING MANIFOLD ASSEMBLY

With the engine supported on the mounting stand in the horizontal flight position, remove the clips which attach the spark plug conduits to the push rod housings. Remove the clamp which attaches the left main magneto conduit to the bracket installed under two supercharger rear housing attaching nuts. Do not remove the bracket at this time. If extended-type rocker box covers are used, it will be necessary to remove the four upper rocker box covers before removing the ignition wiring manifold assembly, since the extended portion of the covers will not permit the main magneto conduits to pass through. In such cases, remove the intake rocker box cover of cylinder No. 9, both intake and exhaust rocker box covers of cylinder No. 1, and the exhaust rocker box cover of cylinder No. 2.

Turn the mounting plate on the engine disassembly stand until the engine is supported in the front-end up position, and lock the mounting plate in this position. Remove the four clips which attach the manifold to four supports installed under the crankcase front section attaching cap screws. These clips are of special design so that they may be withdrawn from the manifold and support after loosening the clamping screw and removing the hook on the clip from the slot in the band.

It will be necessary to raise the engine slightly from the mounting plate at this time in order that the left main magneto conduit may be withdrawn from its present positior between the mounting plate and the supercharger front housing. Install the hoisting eye (Tool No. 83761) on the propeller shaft threads. Remove the five mounting bolts which attach the engine to the mounting plate and, using a chain hoist, raise the engine approximately two inches (50 mm) above the mounting plate. Remove the ignition wiring manifold assembly, including the magneto radio shield assemblies, distributor blocks, and cross-over conduit, by lifting over cylinder No. 1. Reinstall the engine on the mounting plate.

Remove the spark plug terminal contact sleeves from the ends of the ignition cable. Loosen the coupling securing each spark plug terminal elbow to the shielded spark plug conduits and withdraw the elbows and rubber washers. Unscrew the coupling attaching each spark plug conduit to the manifold and withdraw the spark plug conduits and rubber washers from the ignition cables.

Loosen the knurled nut attaching each half of the horseshoe-shaped manifold to the manifold elbows, and withdraw the two halves of the manifold from the ignition cables. Loosen the coupling attaching each manifold elbow to the main magneto conduits and withdraw the two elbows in the same manner.

Remove the two cap screws at the base of each magneto radio shield assembly, which secure the distributor blocks. Remove the two cap screws and washers in slots in each magneto outlet adapter, which attach the adapter to the radio shield. Remove the clamping screws which hold the two halves of the shields together, and remove the shields.

Remove all ignition cable piercing screws in both distributor blocks, and withdraw both distributor blocks from the ignition cables.

Remove the two cap screws which attach each magneto outlet elbow and front flange to the magneto outlet adapters. Withdraw each main magneto conduit casing and magneto outlet front flange from the ignition cables. Withdraw the two magneto outlet adapters in the same manner, allowing the short ends of the cables which were attached to the distributor blocks to pass up through the hole in the bottom of each adapter.

Unscrew the knurled nuts at each end of the cross-over conduit. Withdraw the two magneto outlet flanges from the ignition cables, and withdraw the cross-over conduit casing in the same manner.

Discard the ignition cables. Reinstall the distributor blocks, radio shields, magneto outlet adapters, and coil covers in the proper magnetos.

## ROCKER BOX COVERS, ROCKER ARMS, PUSH RODS, AND PUSH ROD HOUSINGS

The following operations should be accomplished with the engine supported in the front-end up position, and the mounting plate locked in that position.

**ROCKER BOX COVERS** Remove the nuts, lock washers, and plain washers from the four rocker box cover attaching studs on all rocker boxes. Speed wrench (Tool No. 84566) is recommended for use in removing rocker box cover attaching nuts. This wrench is provided with a hollow body in which the nuts are contained after removal. Magnet (Tool No. 84770) is recommended for rapid removal of the lock washers and plain washers from the rocker box cover attaching studs. Remove all rocker box covers and gaskets. Discard the gaskets.

**ROCKER ARMS AND PUSH RODS** Remove the cotter pin from the rocker arm hub bolt nut in all rocker boxes. Remove the rocker arm hub bolt nuts. Turn the crankshaft until one valve is contacting its seat and a clearance exists between the rocker roller and the valve stem. To turn the crankshaft, use the turning tool (Tool No. 82284), which is installed on the propeller shaft splines, and two handles (Tool No. 80292). Push out the rocker arm hub bolt, being careful not to damage the threads on the end of the bolt. See figure 53. Remove the two spherical seat washers. Lift the rocker arm and push rod out of the rocker box. Place the push rods in a storage box. See figure 54.

Repeat this operation for removing all rocker arms and push rods. Remove the clamping screw and the valve clearance adjusting screw from all rocker arms using the combination wrench and screwdriver (Tool No. 81900). See figure 55. WARNING: The valve clearance adjusting screw must be removed socket end first. There is a flange on the outside diameter of the screw at the socket end which will not permit removal of the screw slotted end first.

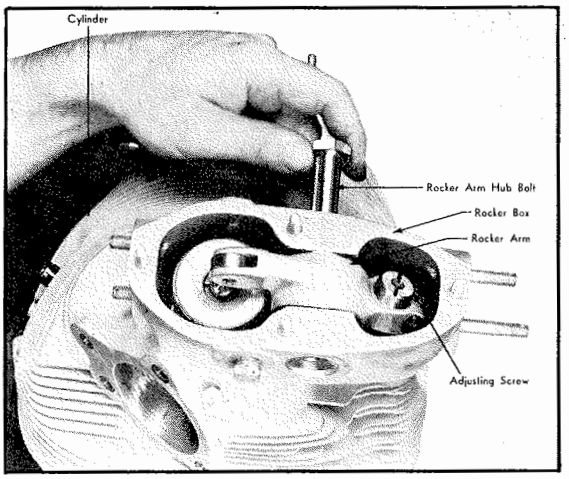



**Fig. 53. Removing or Installing Rocker Arm Hub Bolt**

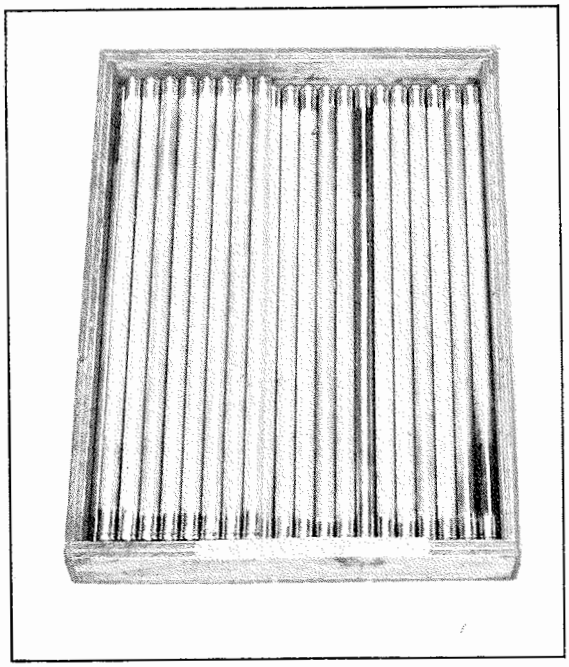


**Fig. 54. Push Rod Housing Storage Box**

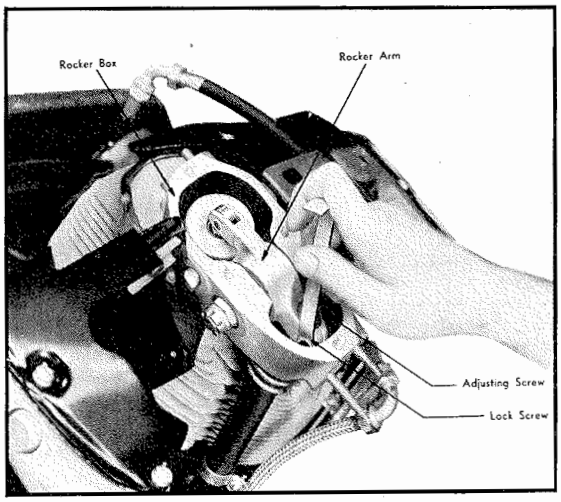



**Fig. 55. Loosening or Tightening Adjusting Screw Lock Screw**

Press the rocker arm bearing out of each rocker arm using an arbor press and the plug and collar (Tool No. 83444) designed for this purpose. See figure 56. Place the rocker arms, bearings, clamping screws, and adjusting screws in a box having 18 individual compartments, one for each rocker arm assembly, in order that the parts of each assembly may be kept together. See figure 57.

**PUSH ROD HOUSINGS** Loosen the clamps at each end of each push rod housing. Slide the housing inward, toward the crankcase front section. Lift the rocker box end of the push rod housings up, and remove the housings by pulling outward, away from the engine. Remove the hoses and clamps. Discard the hoses. Spring-type hose clamps

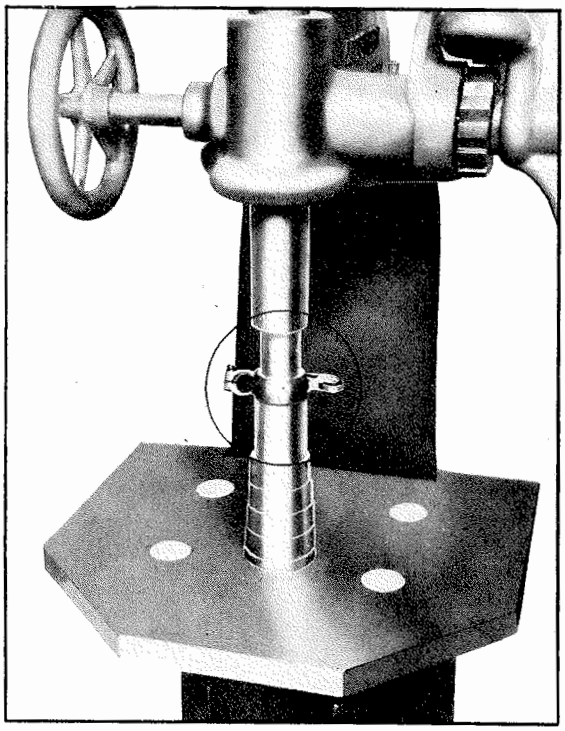


Fig. 56. Removing Rocker Arm Bearing

are removed from the hose connections by absorbing the spring pressure with special pliers, (Tool No. 800687). See figure 58.

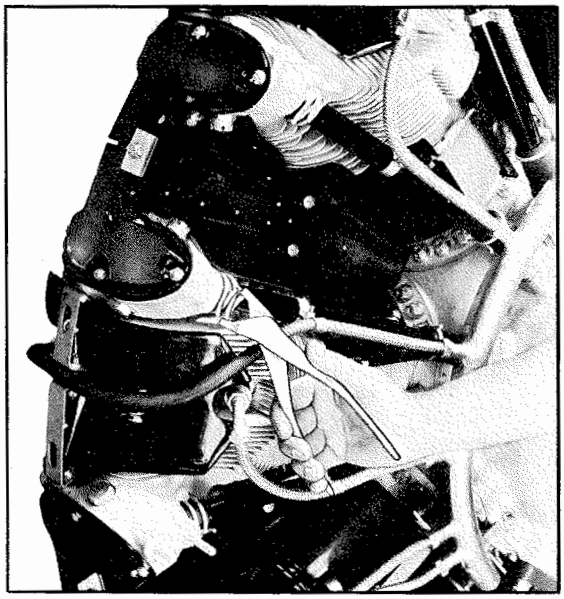


Fig. 58. Removing Push Rod Housing Hose Clamp

Remove the loose-fitting valve tappet ball sockets and springs from all the valve tappets, turning the crankshaft, if necessary, to push

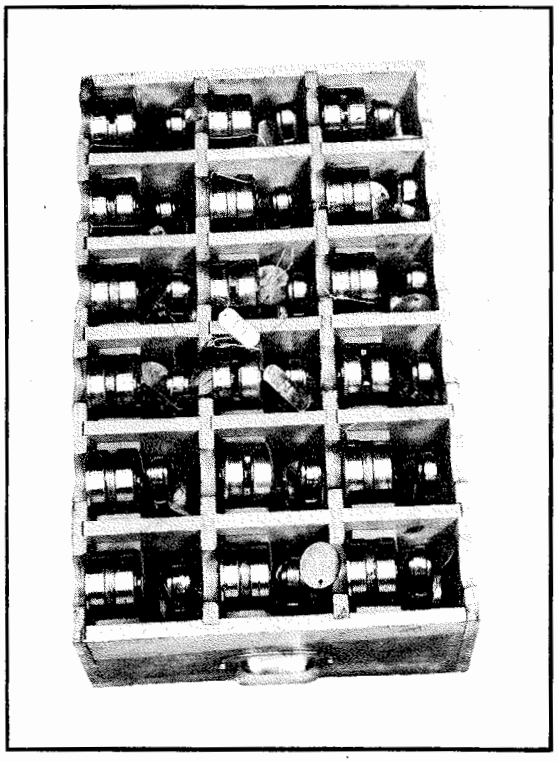


Fig. 57. Rocker Arm Storage Box

Fig. 59. Valve Tappet Storage Box

the socket within reach. Place the ball sockets and springs in a box having 18 individual compartments, one for each tappet and guide assembly, in order that the parts of each assembly may be kept together. See figure 59.

## SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER

Turn the mounting plate on the engine disassembly stand until the engine is supported in a front-end down position, and lock the mounting plate in this position. Remove the nuts and washers which secure the supercharger rear housing to the supercharger front housing. Attach the hoisting eye (Tool No. 83863) to the starter pad on the supercharger rear housing cover, and secure with nuts and washers on all six starter attaching studs. Remove the rear housing and cover assembly. See figure 60. It may be necessary to tap the rear housing lightly at the parting surface using a light fibre mallet to separate the two sections. Lower the rear housing and cover assembly onto a disassembly stand. See figure 61. A drawing of a disassembly stand which is recommended for use is shown in figure 62. Remove the hoisting eye from the starter pad.

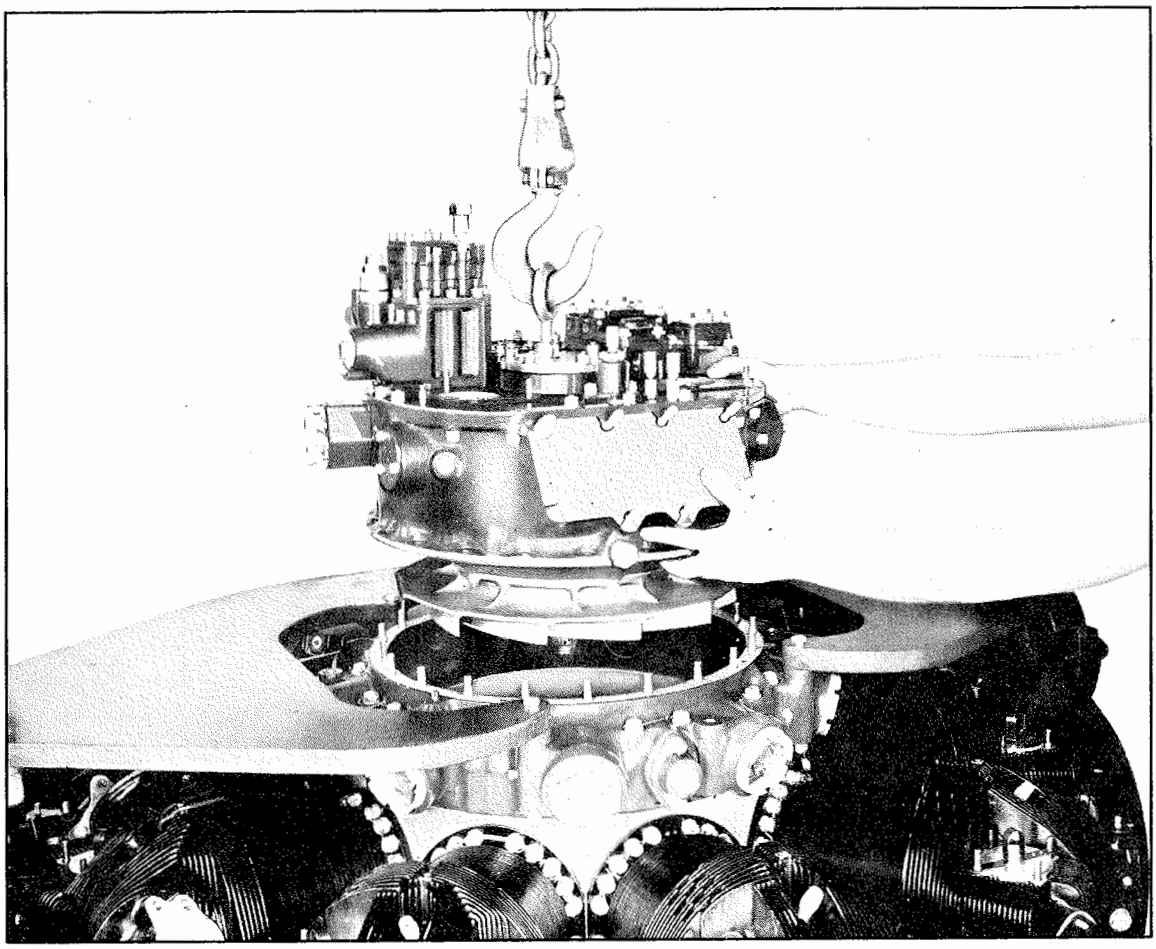


**Fig. 60. Removing Rear Housing and Cover Assembly**

**FUEL PUMP DRIVE** Remove the flanged fuel pump drive-shaft support, drive shaft, and oil seal as one unit from the rear housing. Two ¼-20 tapped holes are provided in the flange of the support in which puller screws (Tool No. 84956) may be inserted to facilitate removal of the assembly. Remove the drive shaft from the support. If the shaft may not be readily removed from the support, strike the antigear end of the shaft using a fiber drift and mallet. Remove the seal, using removing and installing Tool No. 801534. Do not remove the bushings from the support unless they require replacement. Instructions for replacing these parts are included in the chapter entitled REPAIR AND ASSEMBLY OF SUB-ASSEMBLIES, under the sub-title SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER.

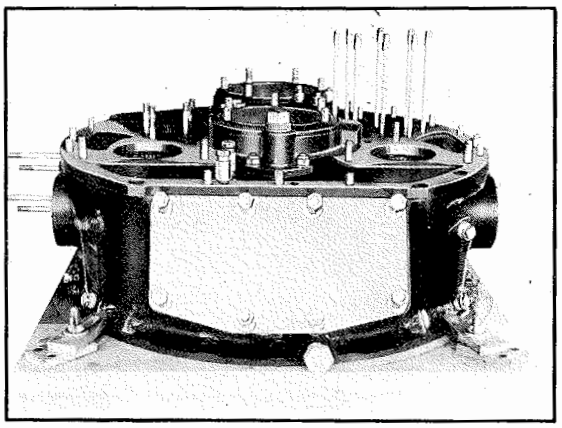


**Fig. 61. Supercharger Rear Housing on Disassembly Stand**

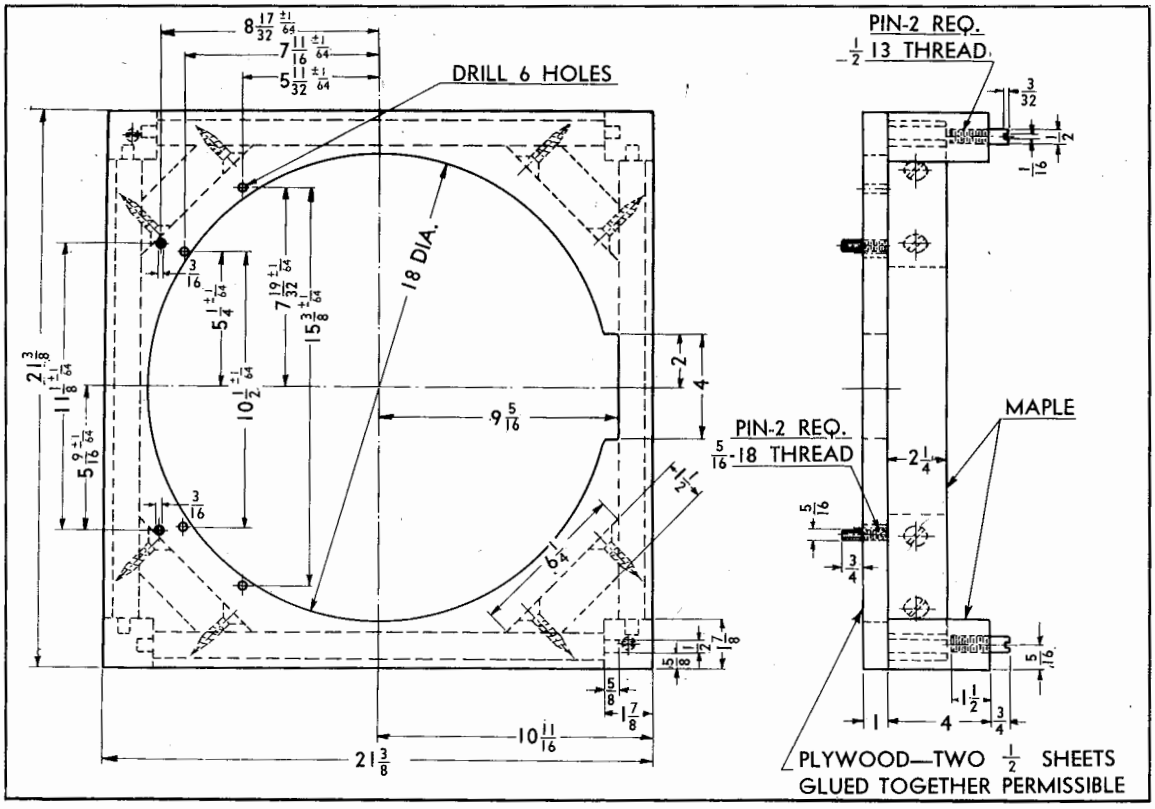



**Fig. 62. Construction Dimensions for Supercharger Rear Housing Assembly Stand**

**CUNO OIL FILTER** Remove the three nuts which hold the Cuno oil filter in the rear housing and remove the filter. See figure 63. Exercise care to prevent damaging the exposed filter cartridge by striking the cartridge against the sides of the hole during removal of the filter. Disassembly of the Cuno oil filter at overhaul is necessary only if inspection of the filter shows that the unit filter cartridge must be replaced. Instructions for replacing the filter cartridge are in-

cluded in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle CUNO OIL FILTER.

**GUN SYNCHRONIZERS** Remove the three cap screws and washers which attach each gun-synchronizer impulse generator or gun-synchronizer substituting cover to the rear housing, and remove the gun synchronizers or substituting covers. If gun synchronizers were installed, remove the flanged gun-synchronizer drive-shaft support and drive shaft together from the rear housing after removal of the gun synchronizer.

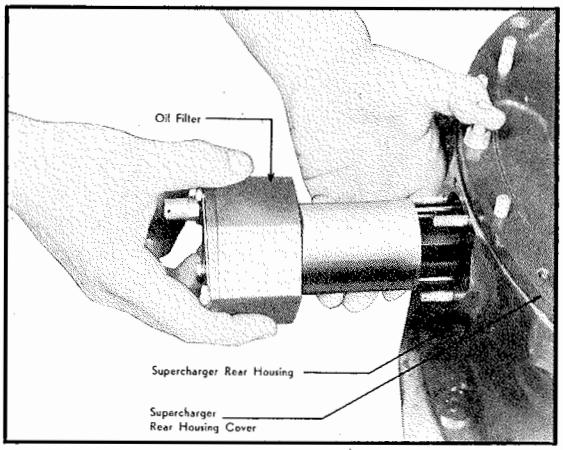



**Fig. 63. Removing Cuno Oil Filter**

Remove the thread-protecting cap and the gun-control cable replacement plug, if used, from the upper plunger housing. Remove the three nuts and washers which attach the upper plunger housing to the lower housing, and remove the upper housing and laminated shim. Withdraw the plunger through the slot in the lower housing. Remove the two plugs from the lower housing.

Loosen the nut which holds the cam on the drive shaft using wrench (Tool No. 82848). Remove the nut and cam together. Do not separate the cam and nut unless replacement of either part is found to be necessary. Remove the drive shaft from the support.

**OIL PUMP** Remove the two palnuts, nuts, and washers which attach the mechanical tachometer drive-shaft housing to the tachometer drive-gear housing cover. Remove the housing. Remove the four palnuts, nuts, and washers which attach the electrical tachometer substituting cover, if used, to the tachometer drive-gear housing cover, and remove the substituting cover. Remove the cap screws and washers which attach the tachometer drive-gear housing and cover to the oil pump cover, and remove the housing and cover together. Separate these sections and remove the mechanical and electrical tachometer drive shafts, oil seal rings, and oil seal retainers. Withdraw the tachometer drive-gear shaft, oil seal ring, and oil seal ring retainer from the oil pump cover. Remove the eight nuts and washers which attach the oil pump cover to the oil pump body and remove the cover. Lift the oil pressure pump drive gear and idler gear out of the oil pump body. Remove the cap screw which secures the lower part of the oil pump body to the rim of the supercharger rear housing cover using wrench (Tool No. 800684). Remove the oil pump body. Remove the oil pump body end plate, through which the oil pump drive shaft passes, from the oil pump body. Loosen the oil pump drive shaft nut while holding the coupling gear using wrench (Tool No. 82676). See figure 64. Remove the nut, washer, oil pump drive coupling, and oil pump drive shaft. Lift the oil suction pump idler gear and shaft out of the oil pump body.

Remove the oil pressure relief valve assem-

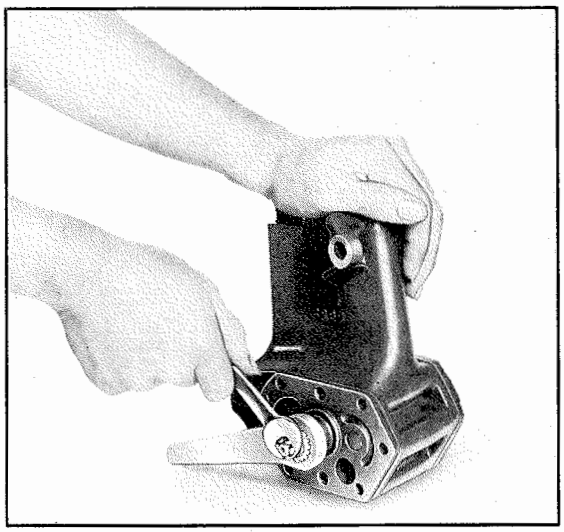


**Fig. 64. Loosening Oil Pump Shaft Coupling Nut**

bly, including the cap, adjusting nut, relief valve washers, relief valve nut, relief valve spring, and valve. Remove the relief valve body using wrench (Tool No. 83660). See figure 65.

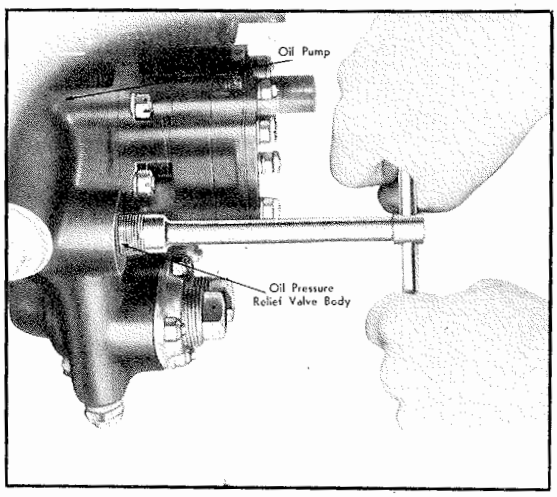



**Fig. 65. Removing Oil Pressure Relief Valve Body**

Remove all plugs from the oil pump body. If an oil check valve is used, remove the retainer, spring, and valve with ring. If the oil check valve has been previously removed, remove the packing ring from the recess in the upper left side of the oil pump body where the oil check valve was formerly located. Remove the oil inlet and outlet flanges.

**DUAL ACCESSORY DRIVE** Remove the four palnuts, nuts, and washers which attach the lower accessory drive substituting cover, if used, to the dual accessory drive housing cover, and remove the substituting cover. Remove the palnut, nut, and washer from the stud located directly to the right of the lower drive. Remove the four palnuts, nuts, and washers which attach the upper accessory drive substituting cover, if used, to the dual accessory drive housing cover, and remove the substituting cover. Remove the two 7/16 inch (11.11 mm) hexagonal head extended nuts on the upper rim of the dual accessory drive housing cover, and remove the cover. Remove all oil passage plugs from the cover.

Lift the upper and lower accessory drive gears, the dual accessory drive idler gear and intermediate gear, bolted together, and the splined main driving gear out of the housing. Disassemble the idler gear and intermediate gear by removing the six cap screws which secure these parts together using wrench (Tool No. 82914).

Remove the nuts and washers in recesses in the dual accessory drive housing, using the offset box wrench (Tool No. 800684) for the two 5/8 inch (15.88 mm) hexagon nuts. See figure 66. Remove the extended nut and washer on the rim of the housing at the upper right corner, and the two acorn nuts and washers on the under side of the supercharger rear housing flange. Remove the dual accessory drive housing. Remove all oil passage plugs from the housing.

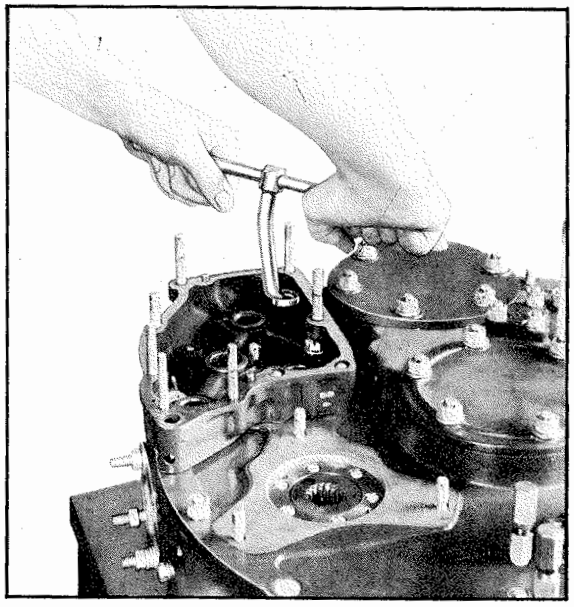


**Fig. 66. Loosening or Tightening Hidden Nut in Dual Accessory Drive Housing**

**SUPERCHARGER DRAIN VALVE** Remove the supercharger drain valve assembly from the supercharger rear housing, including the plug, washer, valve housing, disk gasket, bushing, valve body, washer, and steel venturi tube.

**OIL TANK VENT CONNECTION** Remove the oil tank vent connection from the supercharger rear housing cover.

**CLUTCH CONTROL VALVE OR SUBSTITUTING COVER** Remove the three palnuts, nuts, and washers which attach the two-speed clutch control valve substituting cover to the rear side of the supercharger rear housing cover and remove the substituting cover.

On two-speed engines, remove the three palnuts, nuts, and washers which attach the two-speed clutch control valve housing to the rear side of the rear cover, and remove the valve assembly. Remove the nut on the threaded end of the valve and remove the valve, spring, washer, and packing from the housing. Discard the packing. Withdraw the oil control valve sleeve from the rear cover.

**STARTER SHAFT OIL SEAL** Remove the 12 accessory drive and starter shaft oil seal packing retainer screws. Some engines use fillister head screws, locked by shakeproof lock washers, in this location. Engines of current manufacture use flat head screws, locked by staking into a groove in the retainer attaching flange. The flat head screws may be best removed by inserting a screw driver squarely in the screw slot, rapping the end of the screwdriver sharply using a fiber mallet to loosen the screw, and then removing the screw using the screwdriver. Tighten three screws having a No. 10 - 32 thread into the three tapped holes in the retainer to remove the retainer. Remove the sintered packing, starter dog, and aluminum spacer.

**GENERATOR AND MAGNETO DRIVE OIL SEALS** Remove the generator substituting cover. Remove the six fillister head screws and shakeproof lock washers which attach the generator drive oil seal retainer to the rear cover. Tighten two screws having a No. 10 - 32 thread into the two tapped holes in the retainer to remove the retainer. Remove the generator drive oil seal collar using puller (Tool No. 84983). See figure 67. Remove the sintered seal, diaphragm, flanged thrust washer, and spring. Discard the diaphragm. Remove the corresponding parts from the two magneto drive oil seals in the same manner, using the same puller. See figures 68 and 69. Discard the diaphragm from these seals.

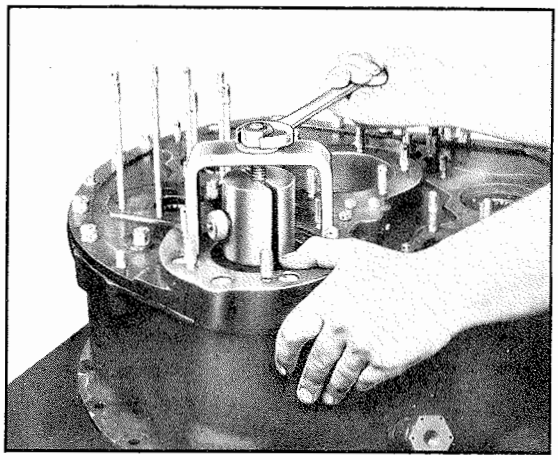


**Fig. 67. Removing Generator Drive Oil Seal Collar**

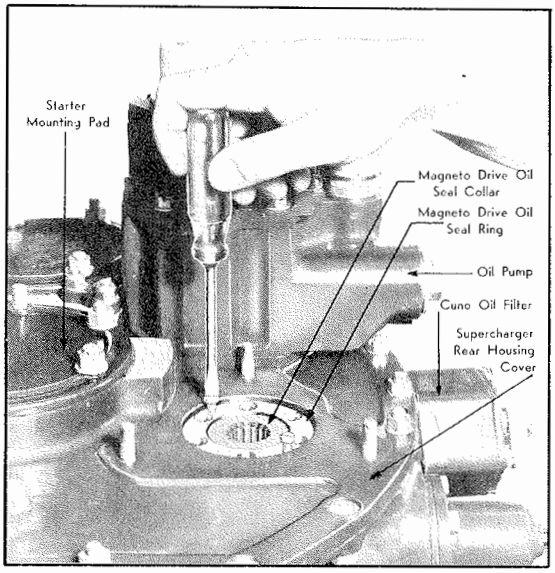



**Fig. 68. Removing Magneto Drive Oil Seal Ring**

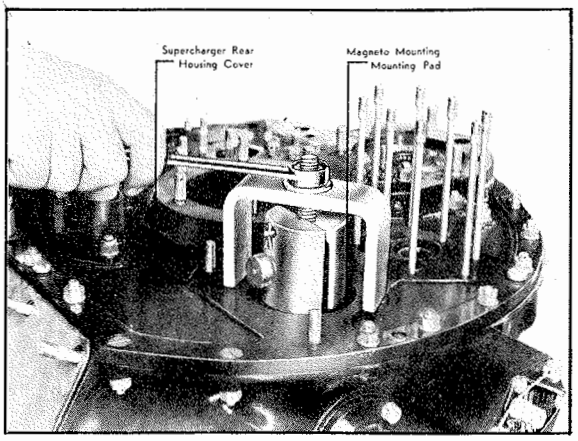



**Fig. 69. Removing Magneto Oil Seal Collar**

**SUPERCHARGER REAR HOUSING COVER** Remove all gaskets remaining on the supercharger rear housing cover. Remove all palnuts, nuts, washers, and machine screws from the rim of the rear cover. See figure 70. Remove the magneto conduit attaching bracket. Remove the three slotted round nuts under the generator

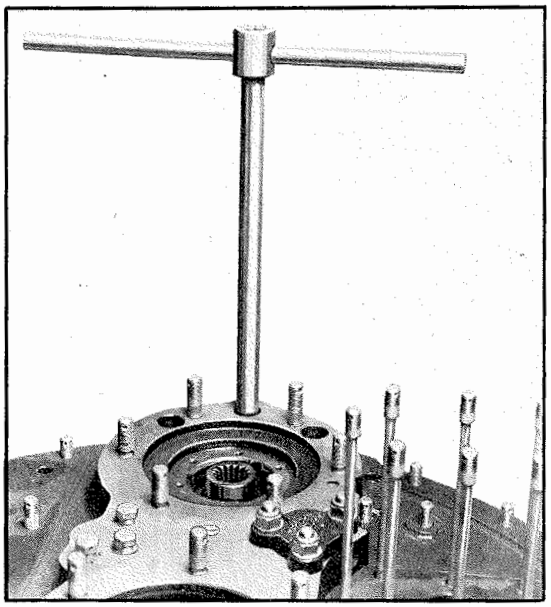


**Fig. 70. Removing or Installing Slotted Round Nut in Supercharger Rear Housing Cover**

mounting pad using lug wrench (Tool No. 83381). Remove the three puller hole plugs and gaskets from the rim of the rear cover, and insert in their place three pullers (Tool No. 83648). Screw down evenly on the pullers to remove the rear cover. See figure 71. If necessary, tap the edge of the rear cover lightly using a fiber mallet to separate the cover from the housing. It it appears that too much force on the pullers is required to remove the cover, check again to insure that all attaching nuts and screws have been removed. Continue turning down evenly on the pullers until the cover is loose on the rear housing. Before lifting off the rear cover, check to insure that all the accessory drive gears will remain in the rear housing. If the magneto or generator drive shafts have remained in the rear cover, tap the end of the shafts using a fiber drift and mallet until the shafts drop into the rear housing. If it is necessary to tap the generator drive-gear shaft out of the rear cover, take care to insure that the drift bears on the exposed end of the shaft and does not slip inside the shaft, since that might drive out the generator drive-gear cup plug which is pressed into the front end of the shaft. Lift off the rear cover and remove the pullers.

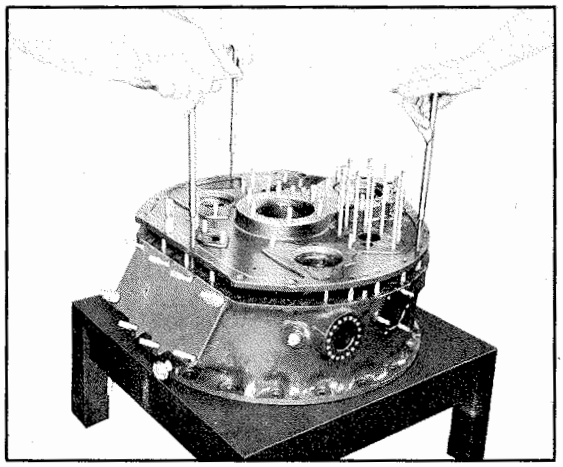


**Fig. 71. Removing Supercharger Rear Housing Cover**

Do not remove the engine oil pressure gage tube which leads from the accsesory drive and starter shaft bushing to the oil pressure gage connection in the rear cover.

**SINGLE-SPEED SUPERCHARGER DRIVE** In engines equipped with a single-speed supercharger drive, proceed with the disassembly as follows: Lift all the accessory driving gears out of the supercharger rear housing. Disassemble the magneto drive gears and the dual accessory drive gear from their respective shafts by removing the attaching screws. Lift out the accessory drive and starter shaft, taking care to insure that the splines on the front end of the shaft do not scratch or score the impeller-shaft bushings. Remove the bronze thrust ring from the recess in the impeller-shaft retainer. Remove the five screws which attach the accessory drive-gear rear plate to the shaft, and remove the plate. Before disassembling the springs and retaining pins from the shaft, observe the following precaution: Wrap a heavy cloth tightly around the accessory drive gear and rear end of the shaft, so that when

the springs are driven out of the shaft they will not be free to fly out and possibly cause injury to shop personnel, but will be contained inside the cloth wrapping. Stand the shaft on the disassembly bench, rear end down, and drive out the springs and retaining pins by striking the springs lightly using a mallet. Remove the cloth from the shaft. Remove the gear by turning approximately 30 deg. to disengage the internal lugs on the gear from the mating ears on the shaft.

Remove the five flat head screws which secure the impeller-shaft retainer to the rear housing. To do this, insert a screwdriver squarely in the screw slot, rap the end of the screwdriver sharply using a fiber mallet to loosen the screw, and remove the screw. Remove the retainer and ring, the shim, the spherical thrust ring, and the steel washer. Remove the ring from the retainer and discard the ring.

Lift the impeller drive gear and pinion out of the supercharger rear housing.

**TWO-SPEED SUPERCHARGER DRIVE (PLATE-CLUTCH TYPE)**

In engines equipped with a two-speed impeller drive of the plate-clutch type, proceed with the disassembly as follows, after removal of the supercharger rear housing cover: Remove the six nuts and washers which attach the low-speed clutch housing to the front side of the supercharger rear housing cover. Hold the housing down firmly against the tension of the low-speed clutch release spring by hand while removing the last two nuts from the housing. Remove the housing, sun gear, clutch disk and plates, thrust washer and spacer, spring, piston with ring, and sleeve. Do not attempt to remove the low-speed clutch piston lock from the piston. If either of these parts requires replacement, the entire assembly must be replaced. The low-speed clutch piston and lock may only be procured together in a matched assembly. Remove the ring from the piston and discard the ring.

Withdraw the intermediate impeller drive shaft and pinion assembly and bell-shaped intermediate impeller drive gear as one unit from the high-speed clutch assembly into which it is splined. Remove the bell-shaped drive gear from the shaft. Remove the small horseshoe-shaped pinion gear retaining washers from the pinion trunnions, and remove the pinions and floating pinion bushings. Remove the shouldered sun gear floating bushing from the shaft.

Lift out the high-speed clutch release spring.

Lift all the accessory driving gears out of the supercharger rear housing. Disassemble the magneto drive gears and the dual accessory drive gear from their respective shafts by removing the attaching screws. Remove and disassemble the accessory drive and starter shaft in the same manner as described previously for engines having a single-speed impeller drive. Remove the bronze thrust ring from the recess in the impeller shaft retainer. Remove the five flat head screws which secure the impeller shaft retainer to the rear housing. Remove the retainer and ring, the shim, the spherical thrust ring, and the splined washer. Remove and discard the retainer oil seal ring.

Lift the impeller drive gear, containing the high-speed clutch assembly, out of the rear housing. Clamp the holding fixture (Tool No. 84668) vertically in a vise, and place the gear in the fixture. Lock the gear in place by tightening the set screw in the fixture. Cut off one bent-up end of the spring steel wire which holds the high-speed clutch assembly in the gear. Grasp the other end of the wire and pull it clear of the gear. See figure 72. Discard the

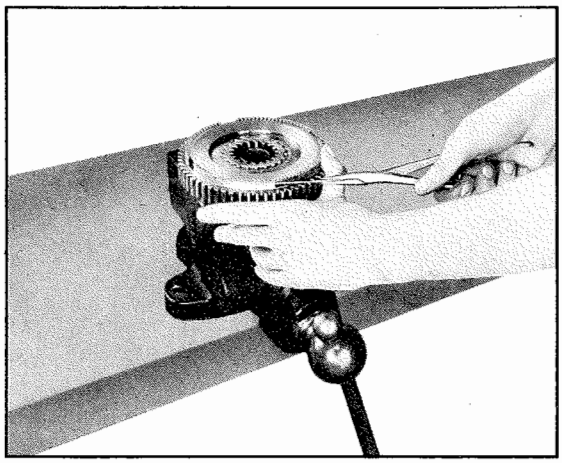


**Fig. 72. Removing the Spring Steel Wire From the High Speed Clutch Assembly**

wire. Remove the gear from the fixture, and remove the clutch retainer, disk and plates, the splined adapter, and the piston with ring. Remove and discard the piston ring.

**TWO-SPEED SUPERCHARGER DRIVE (ROLLER-CLUTCH TYPE)** In engines equipped with a two-speed supercharger drive of the roller-clutch type, proceed with the disassembly as follows after having removed the supercharger rear housing cover: Disassemble the high-ratio clutch which is secured to the front of the supercharger rear housing cover. To accomplish this, remove the six cotter pins, nuts, and flat washers which secure the clutch housing to the rear cover. While removing the last two nuts from the housing, press down firmly on the housing to counteract the force exerted by the clutch release spring. Remove the high-speed clutch housing and intermediate clutch adapter. Remove the thrust washer, spacer, spring, clutch plates and disks, and the piston with its ring. Remove the ring from the piston and discard the ring. Remove the high-ratio impeller drive clutch sleeve with puller (Tool No. 802571).

Remove the roller retainer and cam assembly from the intermediate impeller drive shaft. Lift all the accessory driving gears out of the supercharger rear housing and disassemble these gears as described previously for single-speed engines. Remove the bronze thrust ring from the recess in the impeller shaft retainer. Remove the five flat head screws which secure the impeller shaft retainer to the rear housing. Remove the retainer and ring, the shim, the spherical thrust ring, and the splined washer. Remove and discard the retainer oil seal ring.

Remove the remainder of the two-speed clutch assembly as a unit from the supercharger rear housing. Disassemble these parts by first removing the intermediate impeller drive gear and its internal bushing. Remove the intermediate impeller drive shaft and pinion cage assembly from the impeller drive gear. Remove four cap screws holding the front and rear halves of the pinion cage together and lift off the rear half of the pinion cage. Withdraw the intermediate impeller drive shaft and remove the pinions and bushings from the front half of the pinion cage. Place part in rack. See figure 73.

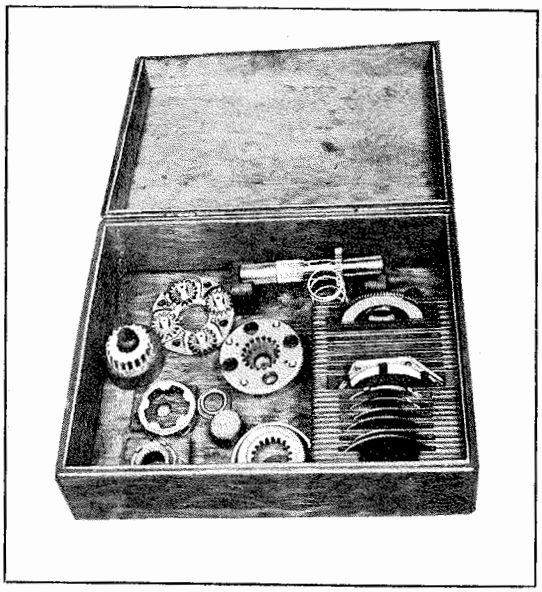


**Fig. 73. Clutch Parts Rack**

**IMPELLER AND IMPELLER SHAFT** Complete the disassembly of the supercharger rear housing, in all engines as follows: Place the rear housing, with the diffuser plate up, on a bench which is covered with a fiber pad larger in diameter than the rear housing. The fiber pad and bench should have holes drilled in locations corresponding to the stud locations on the antipropeller side of the rear housing. The drilled holes should be large enough in diameter and depth to accommodate the rear housing studs. Place the rear housing on the bench so that the studs project into the drilled holes and so that the rear housing rests on the rear cover parting surface. This procedure insures that the studs will not be damaged during the following operations. Clamp the rear housing tightly to the bench in this position. Place strips of light cardboard between the impeller vanes and the diffuser plate to protect these parts during the following operations.

Bend the tab of the impeller nut lock out of the slot in the nut. Install the impeller holding tool (Tool No. 802395) and adapter (Tool No. 84534) on the supercharger rear housing. With the impeller locked firmly, remove the

impeller nut using lug wrench (Tool No. 802275). See figure 74. Remove the impeller nut lock and the front impeller shaft oil sleeve with rings. Remove the oil seal rings from the

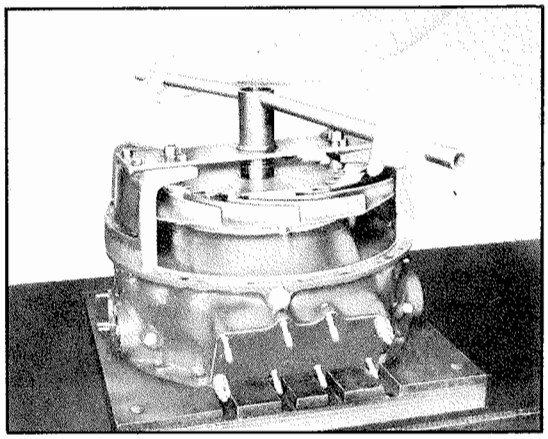


**Fig. 74. Loosening or Tightening Impeller Nut**

sleeve and discard the rings. Remove the impeller locking tool and adapter. Remove the impeller from the impeller shaft using puller (Tool No. 800304). See figure 75. Place impel-

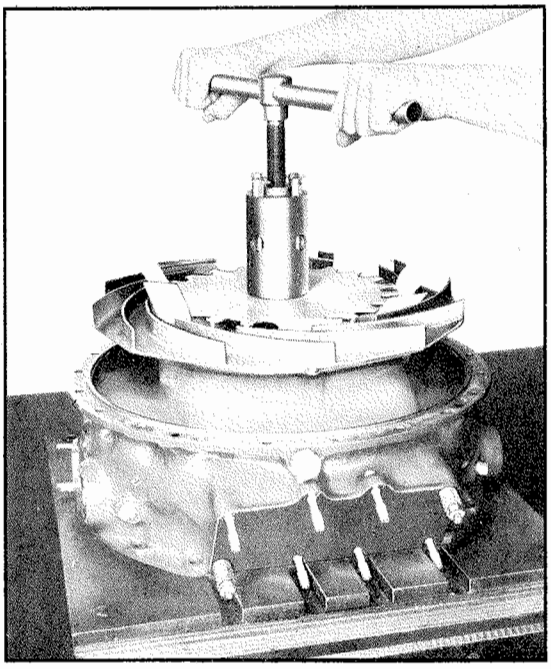


**Fig. 75. Removing or Installing Impeller**

ler in box as shown in figure 76. After removal of the impeller, remove the impeller shaft from the rear housing. Remove the rear impeller shaft oil sleeve with rings and the bronze washer from the impeller shaft. Remove and discard the oil seal rings.

Remove the plate covering the entrance to the induction passage in the supercharger rear housing.

Do not remove the manifold pressure gage tube which crosses the induction passage in the rear housing. Do not remove the copper fuel venturi extension tube which is spun into the lower part of the rear housing. Instructions for replacing the spun-in fuel venturi

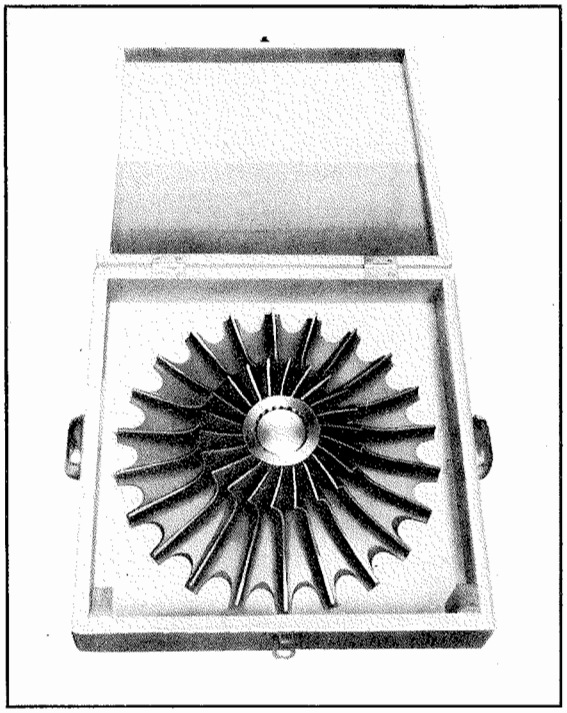


**Fig. 76. Impeller Storage Box**

extension tube if the tube is found to be loose are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER.

Do not remove the diffuser plate from the supercharger rear housing unless inspection indicates that replacement of the diffuser plate is necessary. Instructions for removing the diffuser plate for replacement with a new part are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER.

# CYLINDERS AND PISTONS

**CYLINDERS** Turn the mounting plate until the engine is supported in the front-end up position, and lock the mounting plate in this position. Begin the removal of the cylinders with a cylinder adjacent to the master rod cylinder. Turn the crankshaft using turning tool (Tool No. 82284), installed on the propeller shaft splines, and two handles (Tool No. 80292) until the piston in the cylinder being removed is at the top of its stroke. WARNING: It is important that the master rod cylinder be removed last. Refer to the engine data plate for the location of the cylinder in which the master rod is located.

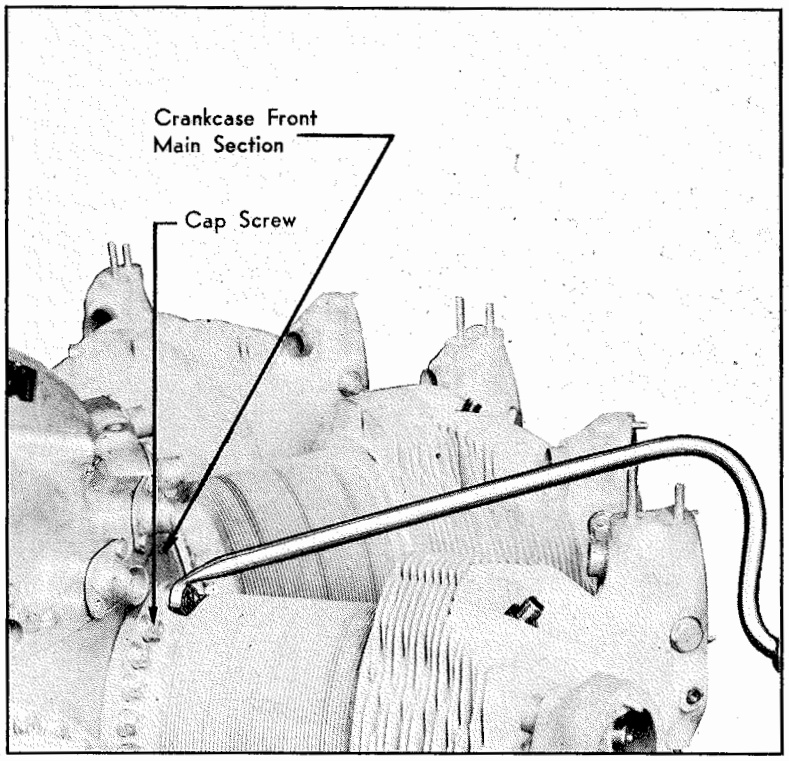



**Fig. 77. Removing Cylinder Hold Down Cap Screw**

Remove the lock wire from the cylinder hold-down cap screws attaching the cylinder which is being removed, to the crankcase. Loosen the cap screws using wrench (Tool No. 82750) for 9/16 inch (14.29 mm) hexagonal cap screws or wrench (Tool No. 82860) for ½ inch (12.70 mm) hexagonal cap screws. See figure 77. Remove the cap screws and spherical seat washers from the cylinder flange. Speed wrench (Tool No. 83131) is recommended for the removal of 9/16 inch (14.29 mm) hexagonal cylinder hold-down cap screws after loosening. Speed wrench (Tool No. 83130) is similarly recommended for ½ inch (12.70 mm) hexagon cap screws. Remove the cylinder by pulling out straight until it is clear of the piston. See figure 78. Clamp a cylinder-fin protector (Tool No. 800259) around the cylinder head to protect the lower cylinder head fins. Install a connecting-rod protector (Tool No. 83596) on the cylinder pad, attaching it temporarily with two cap screws, to prevent the rod from striking the crankcase. See figure 79.

**PISTON PIN RETAINERS** Remove the two coil-spring type piston pin retainers using removing tool (Tool No. 84377). Insert the hook on the tool between two of the spring coils at a point on the center line of the piston

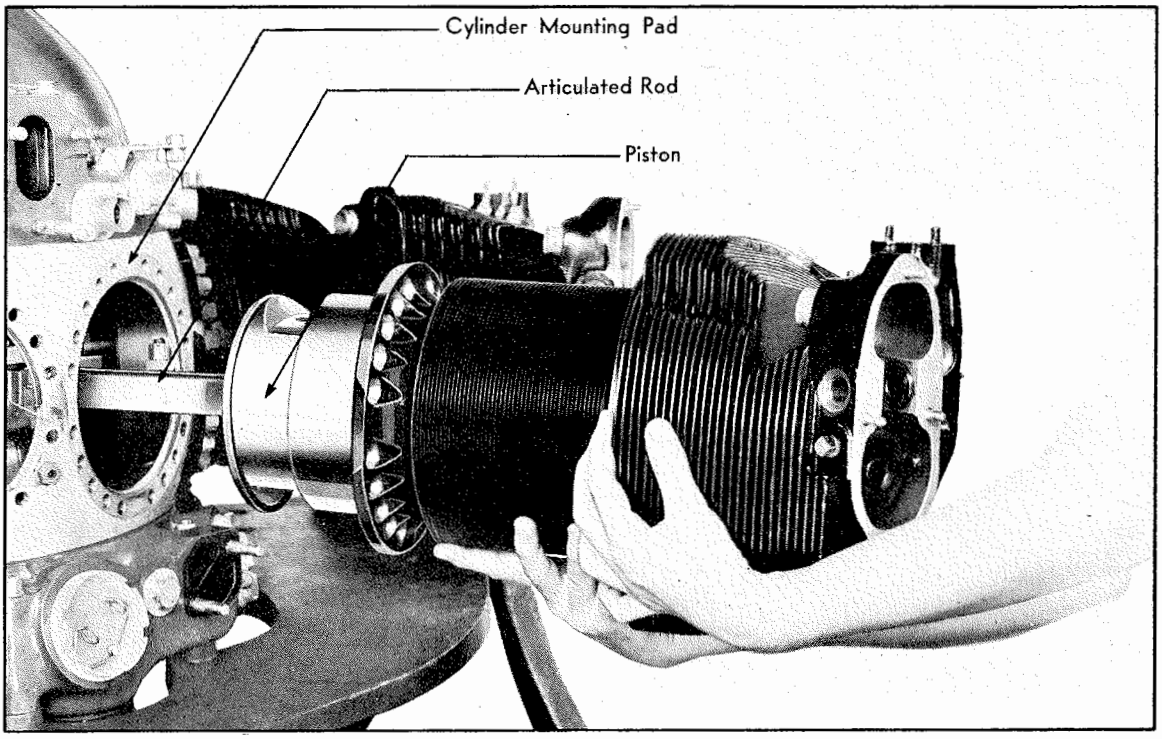



**Fig. 78. Removing Cylinder**

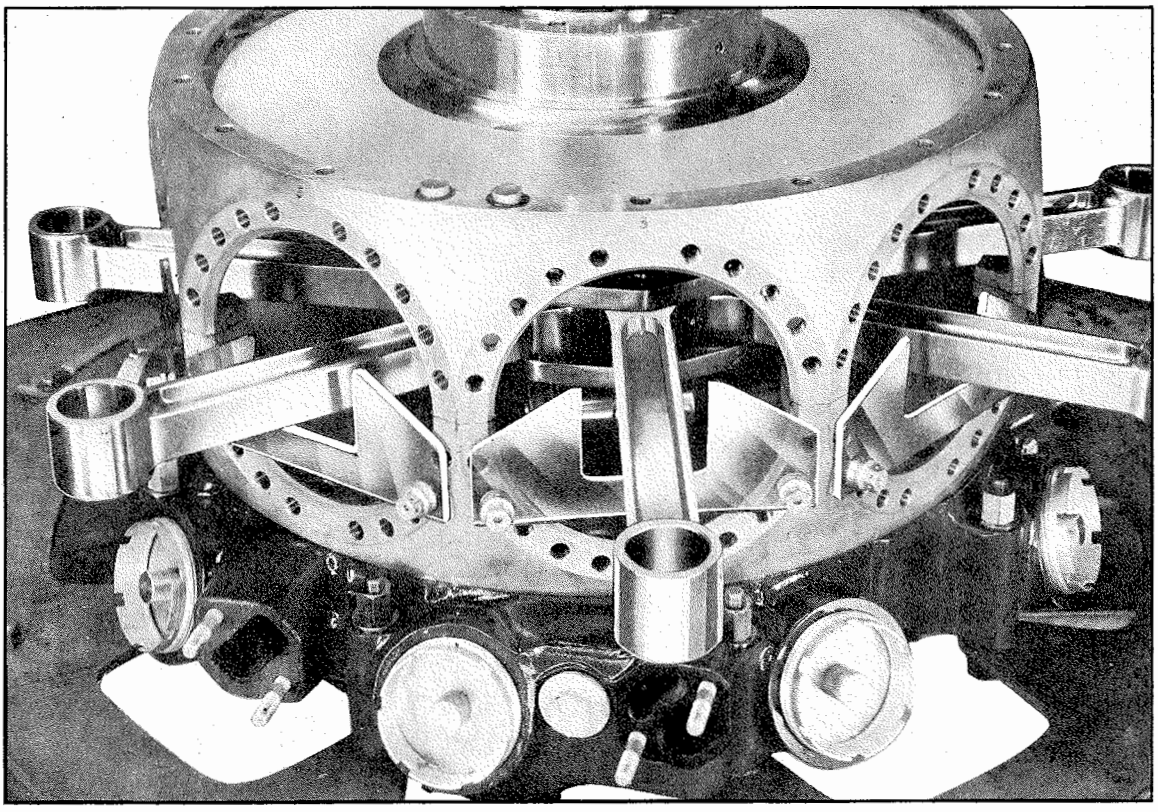


**Fig. 79. Location of Articulated Rod Protectors**

pin hole nearest the crankshaft. Turn the handle of the tool 90 deg. to engage the ears of the hook with the spring coils, rest the aluminum fulcrum block on the piston skirt and apply pressure on the handle of the tool in the direction of the crankshaft to remove the retainer. See figure 80. When removing

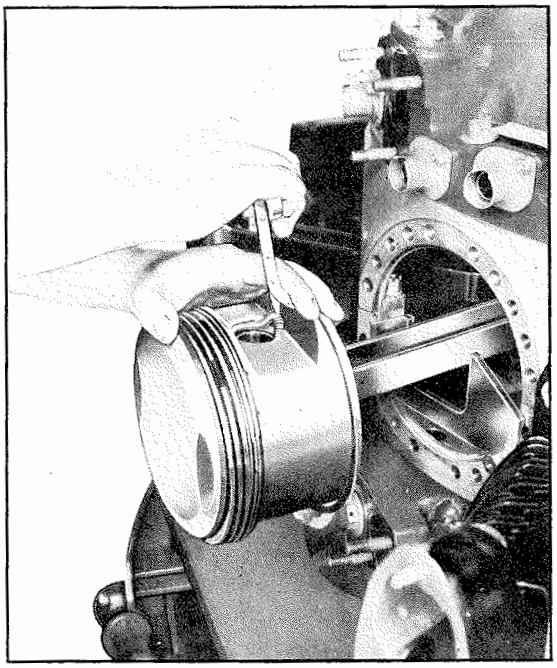


**Fig. 80. Removing Piston Pin Retainer**

a retainer, place one hand over the piston pin hole to catch the spring when it comes out of its groove. Discard all used piston pin retainers.

**PISTON PINS** Remove the piston pins. If the piston pins are so tight in the piston that they may not be removed by hand, use the piston pin removing tool (Tool No. 83243). Encircle the piston with the felt-lined stirrup of the tool and turn the spindle to force out the piston pin. See figure 81. Place piston pins in rack similar to that shown in figure 82.

**PISTONS AND PISTON RINGS** Lift the piston off the connecting rod after removal of the piston pin. Remove and discard the piston rings.

Remove the remaining cylinders and pistons individually, starting with the cylinder adjacent to the cylinder just removed in the direction away from the master rod cylinder,

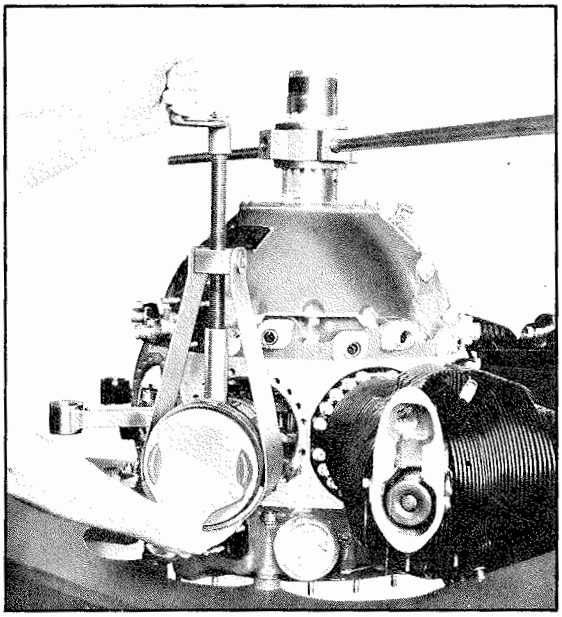


**Fig. 81. Removing Piston Pin**

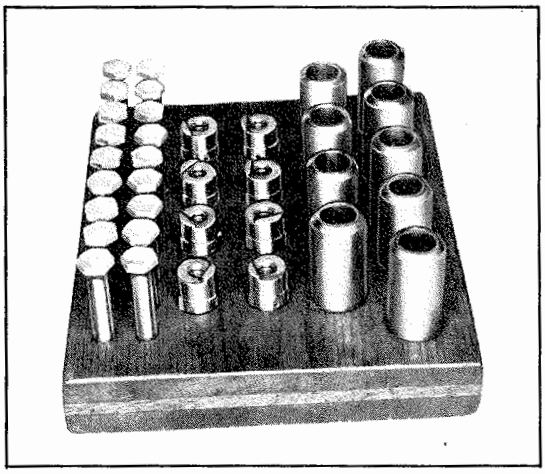


**Fig. 82. Piston Pin and Knuckle Pin Rack**

in the same manner as previously described. Each time, turn the crankshaft until the piston in the cylinder to be removed is at the top of its stroke before removing the cylinder hold-down cap screws. Remove the master rod cylinder and piston last. Place the pistons on a rack similar to that shown in figure 83.

**VALVES AND VALVE SPRINGS** Place a cylinder on a valve assembly and disassembly block (Tool No. 80262). To loosen the carbon around the valve locks and in the lock grooves, procure a fiber drift of

circular cross-section approximately 1¼ inch (31.75 mm) in diameter. Place one end of the drift on the top center of the valve spring upper washer, hold the drift in a position concentric with the valve stem, and strike the drift squarely on the other end to loosen ac-

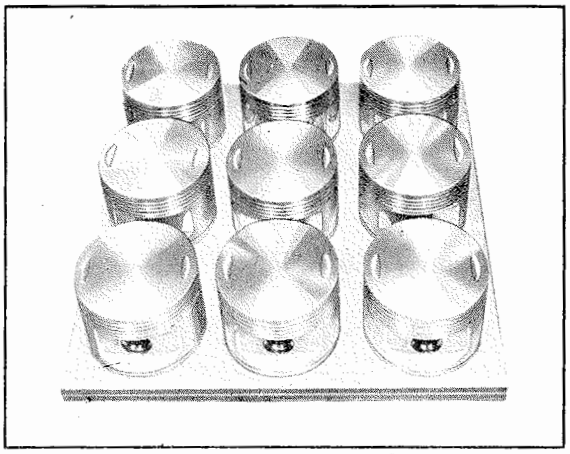


**Fig. 83. Piston Rack**

cumulated carbon. These precautions are necessary in order that the valve spring upper washer will not be cocked when struck, as this may cause serious nicking of the valve stem by the bottom edge of the washer.

Install the valve spring compressor (Tool No. 81409) in place, and insert the rod attached to the tool through the rocker arm hub bolt hole in the rocker box. Compress the springs and remove the split locks. See figure 84. Remove the compressor and lift out the valve spring upper washer, valve springs, and

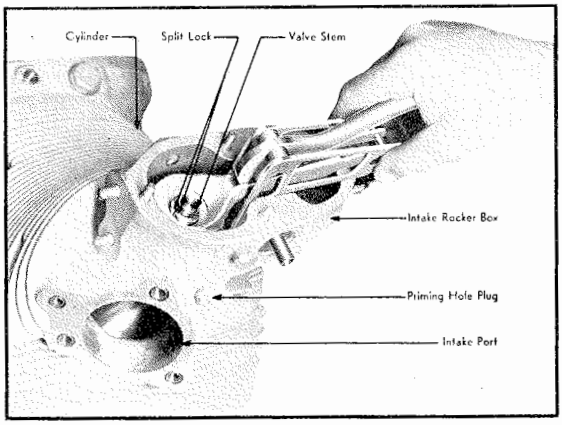



**Fig. 84. Removing Split Valve Locks Using Valve Spring Compressor**

lower washers. Place springs in rack as shown in figure 85.

Remove the corresponding parts from the other rocker box in the cylinder in the same manner. Before lifting the cylinder off the holding block, determine if the valve stems

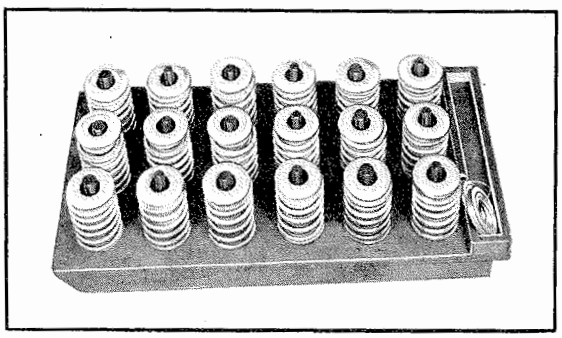


**Fig. 85. Valve Spring Rack**

are nicked or burred. If any nicks or burrs are present, they should be removed by polishing before removing the valves, since a nick or burr on the valve stem may scratch or score the valve guide upon removal of the valve. Remove the cylinder from the block, while

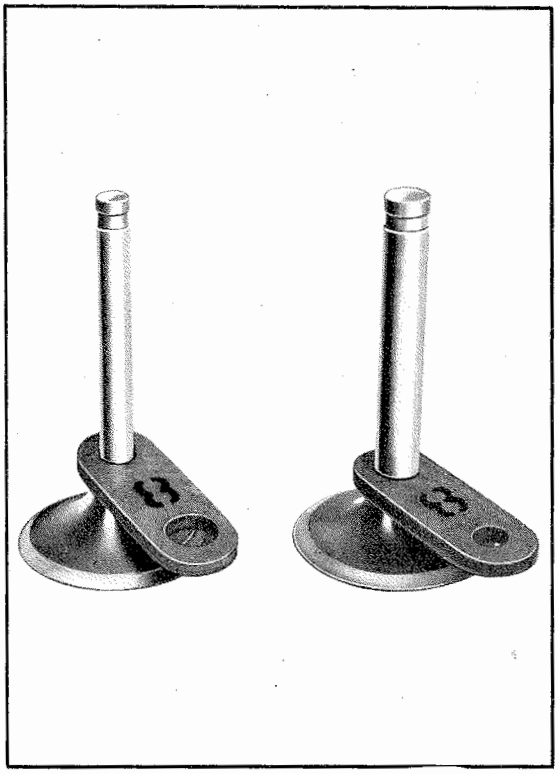


**Fig. 68. Valve Markers**

holding the valves to prevent them from falling out of the guides. Lay the cylinder on its side and remove the valves. Attach a marker to each valve indicating the number of the cylinder in which it was installed. See figure 86. Place valves in rack. See figure 87. Remove the intake port cover (Tool No. 800909) and the exhaust port cover (Tool No. 800910) from the cylinder. Remove the dummy spark plugs.

Repeat these operations on all cylinders.

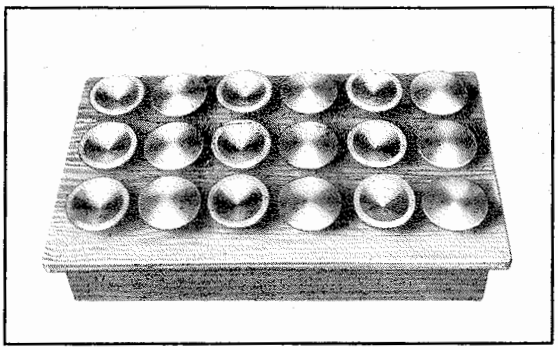


**Fig. 87. Valve Rack**

# CRANKCASE FRONT SECTION

The following operations should be accomplished with the engine supported in the front-end up position and the mounting plate locked in that position.

**VALVE TAPPETS AND VALVE TAPPET GUIDES** Remove the pal-nuts, nuts, and washers from the two tappet guide attaching studs in each tappet guide location, and remove all valve tappet and guide assemblies from the crankcase front section. If a guide cannot be removed by hand, use puller (Tool No. 84802) for this purpose. This puller is provided with a rod which is clamped at one end to the guide. A weight is installed on the rod. Removal of a tight-fitting guide is accomplished by sliding the weight along the rod until it contacts a stop on the outer end of the rod to provide the necessary inertia. See figure 88.

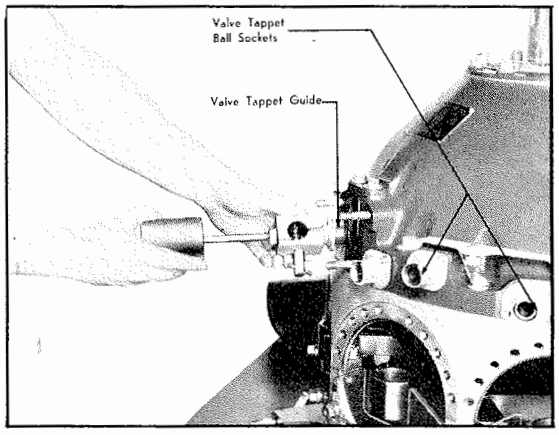



**Fig. 88. Removing Tight Fitting Valve Tappet Guides**

The valve tappets and guides are matched assemblies, and extreme care must be taken when these parts are disassembled to insure that these parts do not become mismatched. Remove the valve tappet circlet from each assembly by inserting the hooked end of the valve tappet circlet removing tool (Tool No. 800087) under the circlet, and pulling out the circlet. See figure 89. Do not attempt to remove the circlets by any other means. Discard the circlets. Push the floating pin out of the

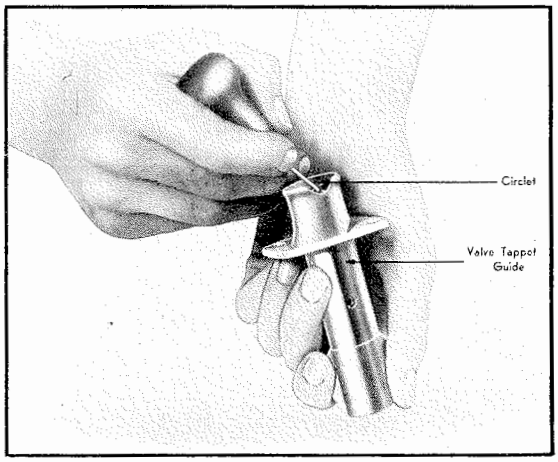



**Fig. 89. Removing Valve Tappet Retaining Circlet**

slotted end of the tappet, and remove the bushing and roller. Place the valve tappets and guides, pins, rollers, and bushings in the box with the valve tappet ball sockets and springs which were previously removed to insure that the matched parts of each assembly are kept together.

**CRANKSHAFT BREATHER TUBE** In engines provided with a crankshaft breather tube, remove the breather tube at this time. To do this, break the lock wire locking the three screws which secure the crankshaft breather screen to the breather tube nut and remove the screws. Remove the screen. Remove the nut using the plug wrench (Tool No. 82195). Remove the

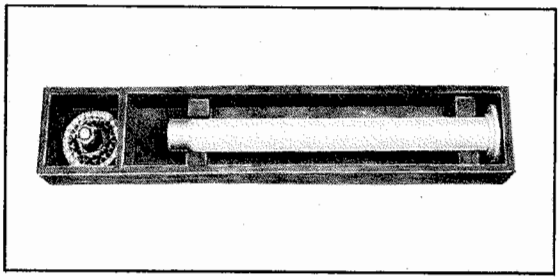


Fig. 90. Breather Tube Rack

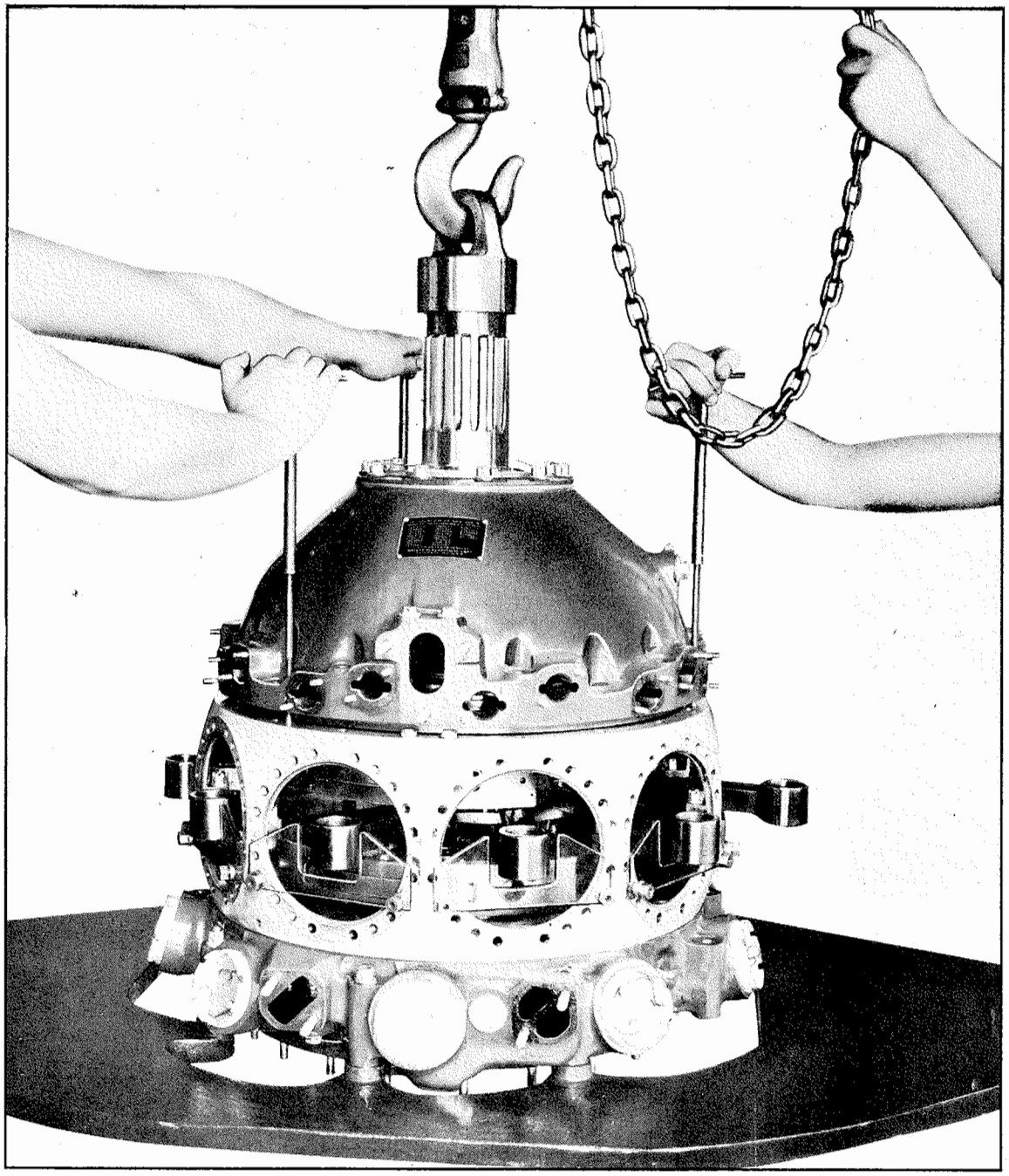


Fig. 91. Removing Crankcase Front Section

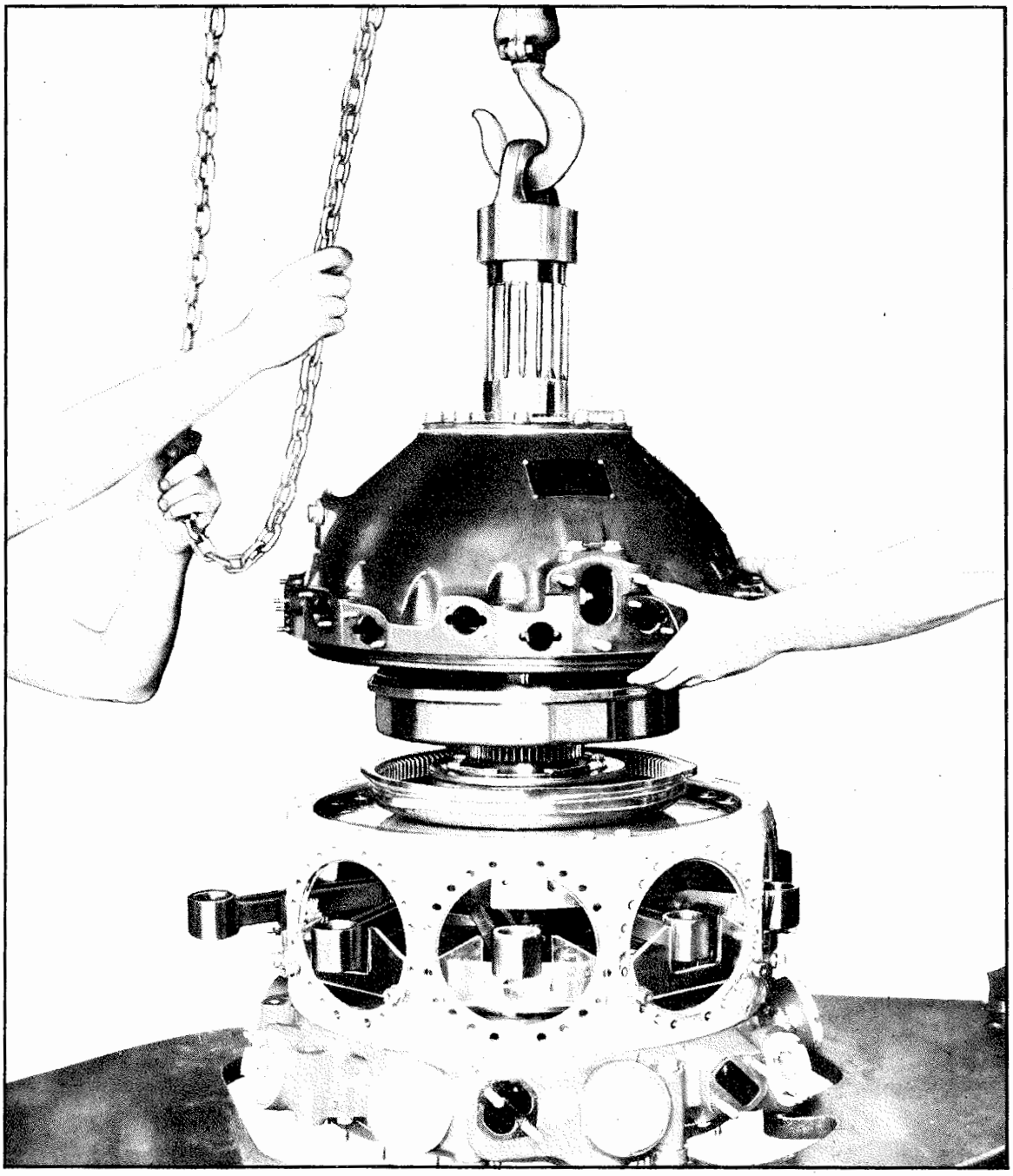


**Fig. 92. Raising or Lowering Crankcase Front Section**

propeller shaft hydro oil connection or cover, whichever is used, and the breather tube front gasket. Remove the breather tube and rear gasket. The breather tube may be more easily removed with a rotating motion. Turning the breather tube helps to overcome the adhesive effect of the oil at the breather tube support. Place the tube in rack as shown in figure 90. In engines which do not employ crankshaft breathing, remove the three screws which secure the propeller shaft front nut lock to the nut. Remove the lock. Remove the nut using wrench (Tool No. 82195). Remove the propeller shaft hydro-oil connection or cover, whichever is used, and front gasket. Remove the adapter and gasket.

Break the lock wire securing the cap screws which secure the crankcase front section to

the crankcase front main section. Remove the cap screws and washers. Remove the four ignition wiring manifold supports.

Remove the three puller hole plugs and gaskets from the rim of the crankcase front section, insert in their place three pullers (Tool No. 83648). Screw down evenly on the pullers until the front section is loose on the crankcase front main section. See figure 91. Install the hoisting eye (Tool No. 83761) on the propeller shaft threads. With the hook on the chain hoist inserted through the hoisting eye, raise the front section until it clears the crankshaft front extension. See figure 92. Insert three crankcase parting flange protectors, (Tool No. 801789) on flange. Lower the front section onto a bench. Remove the pullers and hoisting eye. Reinstall the puller hole plugs and gaskets in the crankcase front section to prevent loss.

**THRUST NUT** With the crankcase front section on a bench, propeller shaft pointing upward, unscrew the thrust bearing nut using wrench (Tool No. 82889). This nut should have been loosened when the engine disassembly was begun. Remove the nut and oil seal rings. Discard the rings.

**CRANKCASE FRONT SECTION SPACER AND FLANGE** The crankcase front section spacer and flange are attached to the crankcase front section by 10 nuts and washers in .666 (3:2) reduction geared engines, and by 10 cap screws and washers in .5625 (16:9) reduction geared engines. Break the lock wire from the attaching nuts or cap screws, and remove the nuts, or cap screws, and washers. Remove the aluminum crankcase front section spacer and the steel flange.

**THRUST BEARING** In engines provided with a .666 (3:2) reduction gear, proceed with the disassembly of the crankcase front section as follows, after removal of the front section spacer and flange: Turn the crankcase front section over so that the propeller shaft points downward projecting through a hole approximately five inches (125 mm) in diameter cut in the bench. Break the lock wire from the two remaining nuts which attach the stationary reduction gear to the interior of the front section, and remove the nuts using a socket wrench. It may be necessary to turn the propeller shaft in order to obtain access to these nuts between the pinion spider arms. Turn the crankcase front section over so that the propeller shaft points upward, and place the entire assembly on an assembly and disassembly block. Figure 93 shows the dimensions of a block recommended for use. The pilot on the top of the block fits in the propeller shaft rear bushing. Remove the circlets from the eight bolts which project through the crankcase front section. Discard the circlets.

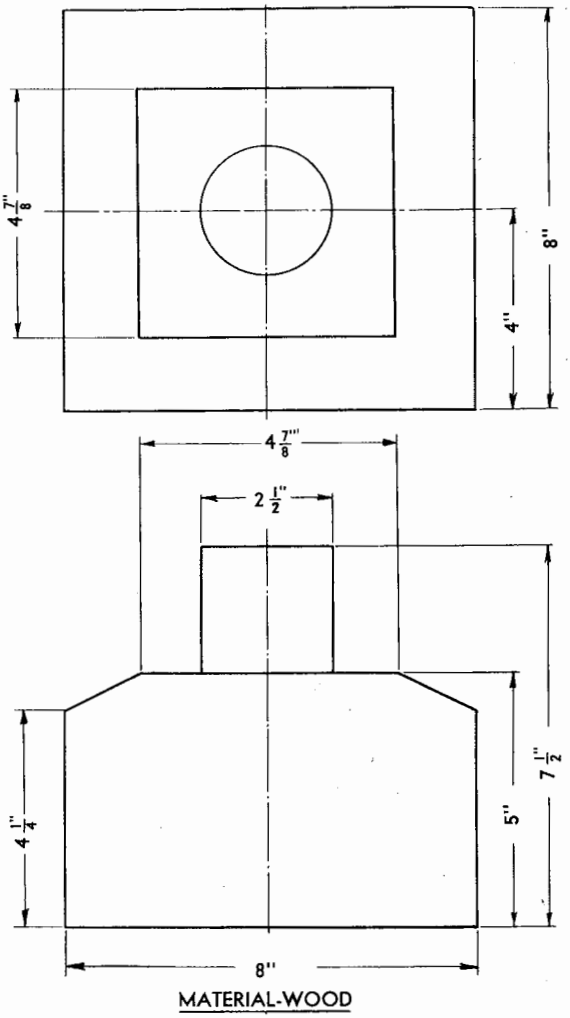



**Fig. 93. Reduction Gear Disassembly and Assembly Block**

In engines provided with a .5625 (16:9) reduction gear, proceed with the disassembly of the crankcase front section as follows, after removal of the front section spacer and flange: Place the entire assembly on the assembly and disassembly block. Remove the two remaining cap screws which attach the stationary reduction gear support to the front section. These two cap screws are in counterbored holes in the front section, under the front section flange.

The following instructions for removal of the thrust bearing apply to both .666 and .5625 reduction geared engines: Lift the crankcase front section off the propeller shaft. The thrust bearing is a tight fit on the propeller shaft and will remain on the shaft. Install the thrust bearing puller (Tool No. 800377) and the halves of the split adapter (Tool No. 800378) on the thrust bearing, locking the tools in place on the bearing with the collar on the puller. Turn the puller handle to raise the puller screw. In engines provided with a thrust bearing having a solid inner race, this will remove the entire bearing. In engines provided with a thrust bearing having a split inner race, this will remove only the front half of the inner race. See figure 94. Lift off the

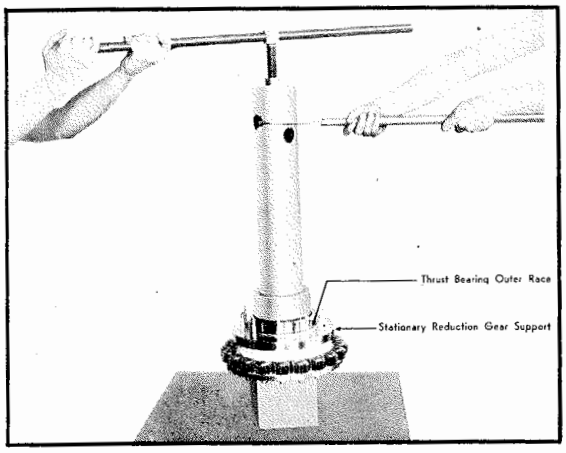



**Fig. 94. Removing Front Half of Thrust Bearing Inner Race**

thrust bearing outer race and the retainer and balls after removal of the inner race front half. Remove the rear half of the inner race using puller (Tool No. 800377) and adapter (Tool No. 801420). See figure 95. Wrap the outer race, retainer, and balls, and the two halves of the inner race together in a cloth or waxed paper. Do not attempt to remove the balls from the retainer. CAUTION: It is very important that the matched parts of each thrust bearing assembly be kept together. Failure of the thrust bearing during engine operation may result from the use of mis-

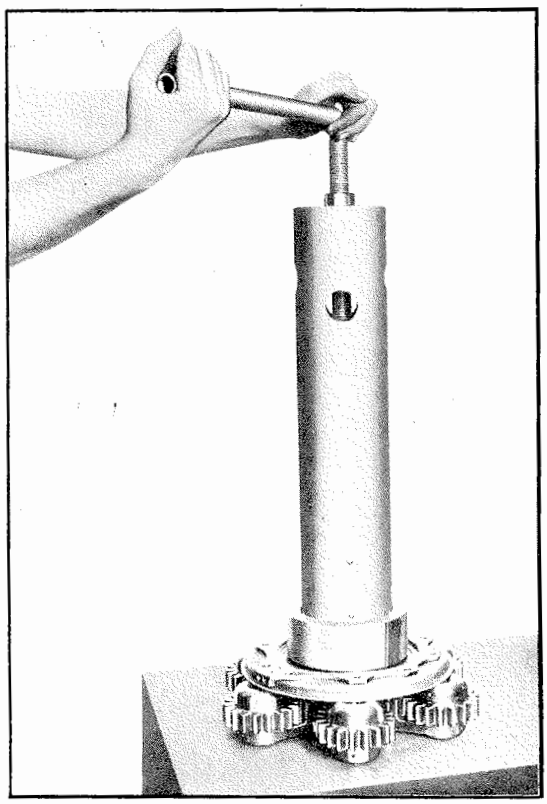


**Fig. 95. Removing Rear Half of Thrust Bearing Inner Race**

matched halves of the split inner race, outer race, and retainer and balls.

Do not attempt to remove the thrust bearing retainer from the front section. Remove all plugs from the crankcase front section. Remove and discard the T-shaped oil seal ring from the front section rear flange.

**PROPELLER SHAFT—.666 (3:2) REDUCTION GEAR** In engines provided with a .666 (3:2) reduction gear, proceed with the disassembly of the propeller shaft as follows, after removal of the thrust bearing: Lift the stationary reduction gear and pinion guard ring off the propeller shaft, and remove the eight stationary reduc-

tion gear attaching bolts. Remove the thrust bearing spacer and ring assembly, using puller (Tool No. 84517) if the spacer is too tight on the shaft to permit removal by hand. Slide the collar on the tool over the three legs to hold the tool in place on the spacer. See figure 96. Remove and discard the rings from

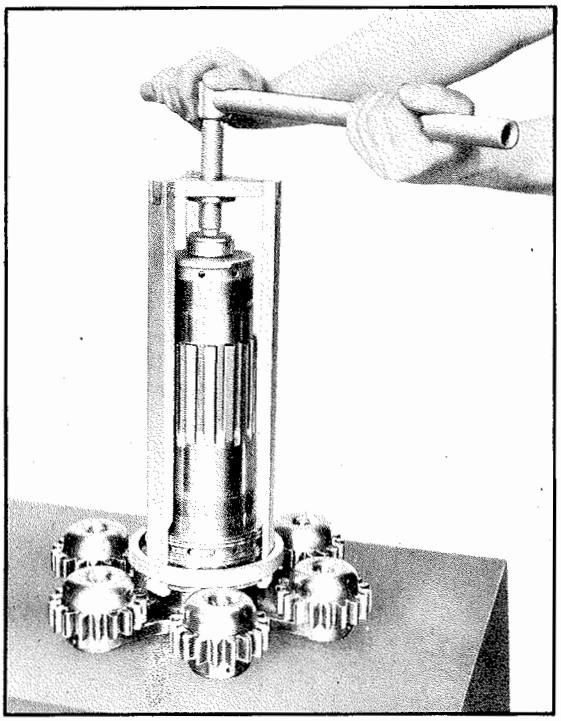


**Fig. 96. Removing Thrust Bearing Spacer and Ring Assembly**

the spacer. Care must be exercised to locate correctly the puller in order to avoid removing the dowel pin which locks the propeller shaft rear bushing in .666 (3:2) reduction geared engines.

Place the propeller shaft in the holding fixture (Tool No. 82258). Remove the cotter pins from the pinion lock bolts. Engage the pinion locking tool (Tool No. 83308) with the teeth of two adjacent pinions, and remove the lock bolts from these pinions using wrench (Tool No. 82812). NOTE: The pinion lock bolts are provided with a left hand thread. Repeat this operation to remove the remaining lock bolts. Remove the pinions from their trunnions. Remove the propeller shaft from the holding fixture. See figure 97.

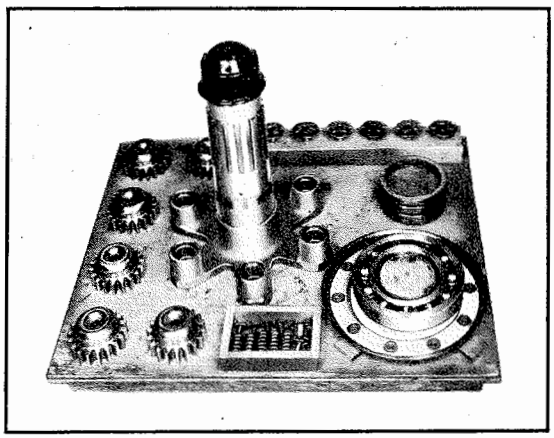


**Fig. 97. Reduction Gearing Parts Rack (3:2)**

**PROPELLER SHAFT —.5625 (16:9) REDUCTION GEAR** In engines provided with a .5625 (16:9) reduction gear, proceed with the disassembly of the propeller shaft as follows, after removal of the thrust bearing: Lift the stationary reduction gear support and pinion guard ring off the propeller shaft.

Lift off the stationary reduction gear. Remove the thrust bearing spacer and ring as-

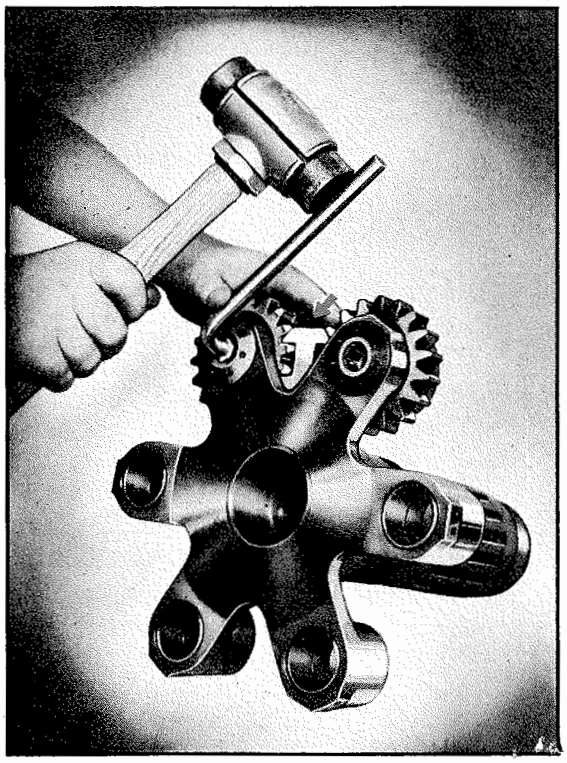


**Fig. 98. Removing Nuts from Pinion Locking Bolts (16:9)**

sembly, using puller (Tool No. 84517) if the spacer is too tight on the propeller shaft to permit removal by hand. See figure 96. Remove the rings from the spacer and discard the rings.

Place the propeller shaft in the holding fixture (Tool No. 82258). Remove the cotter pins from the pinion lock bolt nuts. Using the pinion bolt holding wrench (Tool No. 83507) in the slots in the two bolt heads to prevent the bolts from turning, remove the nuts from these bolts. See figure 98. NOTE: **The pinion lock bolts are provided with a left-hand thread.** Repeat this operation to remove the remaining nuts. Remove the pinions and bushings from their trunnions. Disassemble the pinion carrier from the propeller shaft by removing the 24 cotter pins, nuts, and bolts which secure these parts together. Place part on rack as shown in figure 99. Remove the propeller shaft from the holding fixture.

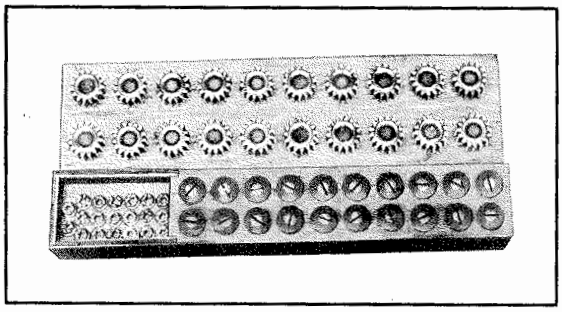


**Fig. 99. Reduction Gearing Parts Rack (16:9)**

**THRUST BEARING, PROPELLER SHAFT AND TORQUEMETER PARTS — .666 (3:2) AND .5625 (16:9) REDUCTION GEARED ENGINES HAVING A TORQUEMETER**

For disassembly of the crankcase front section on engines incorporating a torquemeter, proceed as follows: With the crankcase front section on a block remove the lock wire and the 16 bolts and nuts on the torquemeter cell cover, and remove the cover and valve. The ¼-28 threaded hole is provided in the valve for this purpose. Remove the governor drive assembly or the governor drive substituting cover by removing the four palnuts, nuts, and washers which secure it to the high-pressure oil pump. Remove the lock wire and the two screws which fasten the top of the high pressure oil pump to the top of the torquemeter cell housing. This high pressure oil pump, which supplies oil to the torquemeter cell, may now be removed from the crankcase front section by removing the lock wire and four governor attaching nuts and washers. Remove the lockwire from the cell housing, holding the housing to the case, and remove the housing from the crankcase front section.

In .666 (3:2) reduction geared engines, remove the 10 nuts and washers which secure the crankcase front section steel flange and aluminum spacer to the front section. The bolts on which these nuts were tightened will not drop inside the front section because they are held in place by circlets. Remove the front section flange and spacer.

In .5625 (16:9) reduction geared engines remove the 10 cap screws which secure the crankcase front section steel flange and aluminum spacer to the front section. Remove the flange and spacer.

In engines incorporating a thrust bearing with a solid type inner race, use puller (Tool No. 800377) and adapter (Tool No. 800378) to free the propeller shaft from the crankcase front section. Lift the crankcase front section from the propeller shaft. During this operation the stationary reduction gear may or may not remain in the front section. Therefore, care must be exercised to insure that this gear does not fall and injure any parts. If it remains in the front section, place the front section on a bench, front end down, and lift out the stationary reduction gear.

In engines incorporating a torquemeter and a thrust bearing with a split inner race, remove the thrust nut, the steel flange and aluminum spacer as above. Replace at least four of the cap screws or nuts and a sufficient number of washers to pull the torque arm up tight and hold it securely during the following operation. Do not remove the thrust bearing inner race front half. Remove the screen and nut from the propeller shaft as described earlier in this chapter and pack the propeller shaft with dry ice. When the propeller shaft begins to sweat, blow steam into the thrust bearing around the balls. When the propeller shaft has loosened in the thrust bearing inner

race, stop the steam and lift the crankcase front section immediately from the propeller shaft.

CAUTION: **As soon as those parts which have been in contact with the steam or dry ice are disassembled, insure that they are thoroughly cleaned with gasoline spray and dried in an air stream. Insure that all traces of water are removed.**

Because the stationary reduction gear may or may not remain with the pinion gear assembly when lifting the crankcase front section from the propeller shaft, care should be exercised as above to prevent dropping and possibly damaging this part.

Remove the remaining nuts and washers or the cap screws and washers, as the case may be, and remove the 10 locking circlets from the 10 bolts used on crankcase front sections employing a .666 (3:2) reduction gear. For both .5625 (16:9) and .666 (3:2) crankcase front sections with either a solid or split inner race, proceed with the disassembly as follows: Remove the two remaining cap screws in the front section which bolt into the torque arm support and secure it to the front section. Care should be exercised when removing these cap screws, to prevent wedging or locking of the torque arm and support in the crankcase front section. Place the crankcase front section on a bench, front end down, and lift out the torque arm, rollers, and whole assembly. Some manipulation of these parts may be necessary because of the close clearances between these parts and the crankcase front section. After removing the torque arm assembly, lift out the thrust bearing as a unit.

Disassemble the torque arm and support assembly by removing the balls which hold the parts together. To do this, place the assembly on a bench with the support down. Hold the support and rotate the torque arm on the balls until the circular slot in the torque arm indexes with the similar slot in the support. Push the balls, one by one, out of the circular hole formed by the indexing of these two slots, using a drift between the torque arm splines. The balls are matched with precision with the other details of the assembly, and balls in a particular assembly must be kept. together.

**PROPELLER GOVERNOR DRIVE** Remove the nuts, or cap screws, and washers which attach the propeller governor substituting cover, if used, to the crankcase front section, and remove the substituting cover. Remove the circlet from the governor drive gear shaft and withdraw the governor drive gear and shaft assembly from the interior of the crankcase front section. Discard the circlet. Disassemble the governor drive gear and shaft by removing the six cap screws which secure these parts together.

**REDUCTION DRIVING GEAR** Remove the lock screw from the reduction driving gear nut. Install the reduction driving gear nut box wrench (Tool No. 82670) over the crankshaft extension and on the nut. To prevent the crankshaft from turning while removing the nut, insert a fiber drift rod 1 3/16 inch (30.16mm) in diameter and 8 inches (200mm) long in the piston pin bushing in the master rod. Turn the crankshaft in a counterclockwise direction, viewed from the front, until the fiber rod rests against the crankcase at the cylinder pad location. Loosen the reduction driving gear nut by striking heavily on the end of the wrench using a lead hammer. See figure 100.

Install the reduction driving gear puller (Tool No. 84857) and three adapters (Tool No. 84858) on the gear. Screw the three adapters into three tapped holes in the gear around the hub. Insert a handle through the hole in the puller screw and remove the reduction

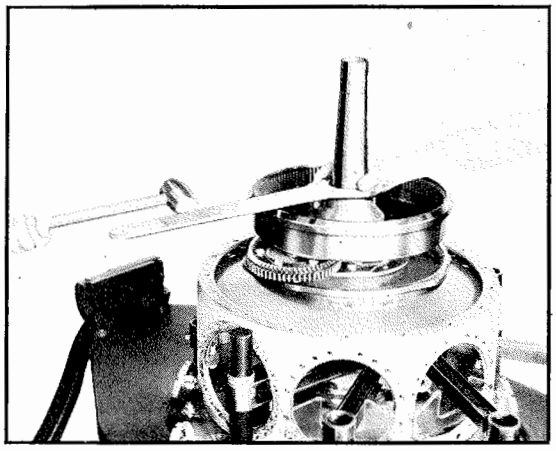


**Fig. 100. Loosening Reduction Drive Gear Nut**

driving gear by turning the handle. See figure 101. Remove the puller and adapters. Remove the fiber rod from the master rod. A hydraulically-operated puller (Tool No. 801207) may also be used with the three adapters to remove the reduction driving gear.

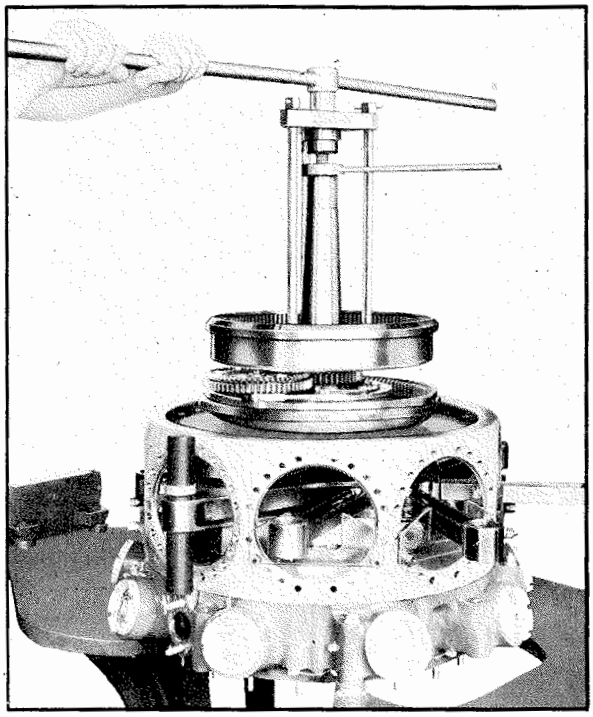


**Fig. 101. Removing Reduction Gear**

## CRANKCASE FRONT MAIN SECTION

Remove the nine cotter pins, nuts, and bolts which attach the two crankcase main section halves together. These bolts pass through internal lugs located between the cylinder mounting pads. Use two special box wrenches (Tool No. 84356) to remove these nuts and bolts. See figure 102. This wrench is provided with a handle curved in such a way that easy access to these nuts and bolts is possible.

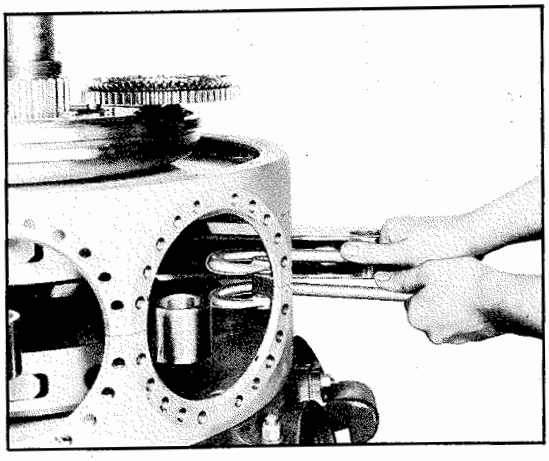


**Fig. 102. Removing Crankcase Internal Attaching Nuts and Bolts**

Lift the crankcase front main section over the crankshaft front extension. Insert three crankcase parting-flange protectors (Tool No. 801789) on each side of the crankcase and place the section on a bench, cam side up. The crankshaft front main roller bearing is of the demountable type. When the front main section is lifted off the crankshaft, the inner race of this bearing remains on the crankshaft and the outer race, retainer, and rollers remain in the bearing ring in the main section.

Lift the reduction driving gear spacer, with rings, out of the bore in the front main bear-

ing ring. Remove the rings from the spacer. Discard the rings.

**CAM AND CAM DRIVE** Break the lock wire from the eight screws which attach the cam drive gear bracket to the crankcase front main section, and remove the screws. Remove the bracket and cam drive gear and pinion assembly. Remove the cam drive gear bracket spacer and the splined cam bearing ring spacer. Lift off the cam. Do not remove the cam bearing ring unless replacement of this part is found to be necessary. Instructions for replacing the cam bearing ring are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle CRANKCASE FRONT MAIN SECTION.

Remove the cotter pin from the cam drive gear and pinion bolt nut. Remove the nut and bolt and the cam drive gear and pinion. Remove the cam drive gear spacer. Disassemble the cam drive gear and the governor drive gear by removing the six cap screws which secure these gears together.

**CRANKSHAFT FRONT MAIN BEARING** Turn over the crankcase front main section so that the section is resting on the cam bearing ring. Remove the crankshaft front main bearing outer race, retainer, and rollers from the front main section. If the bearing outer race is tight in the bearing ring, use the crankshaft front main bearing outer race puller (Tool No. 801508). Before using these tools, remove the bearing retainer and rollers from the outer race. To do this, grasp the projecting sides of all the rollers and pull the rollers toward the center of the bearing, after which the retainer and rollers may be lifted out together. Install the puller over the bearing outer race, swing the hooked end of the hinged arms under the lip of the bearing race, and turn the spreader lock to clamp the arms in position. Remove the race.

Install the crankshaft front main bearing inner race puller (Tool No. 84562) and the four segments of the split adapter (Tool No. 84564) on the inner race of the front main bearing, locking the tools in place on the race with the collar on the puller. Remove the bearing inner race. See figure 103. Remove the puller and adapter and wrap the front main bearing inner race, outer race, and retainer and rollers together in waxed paper.

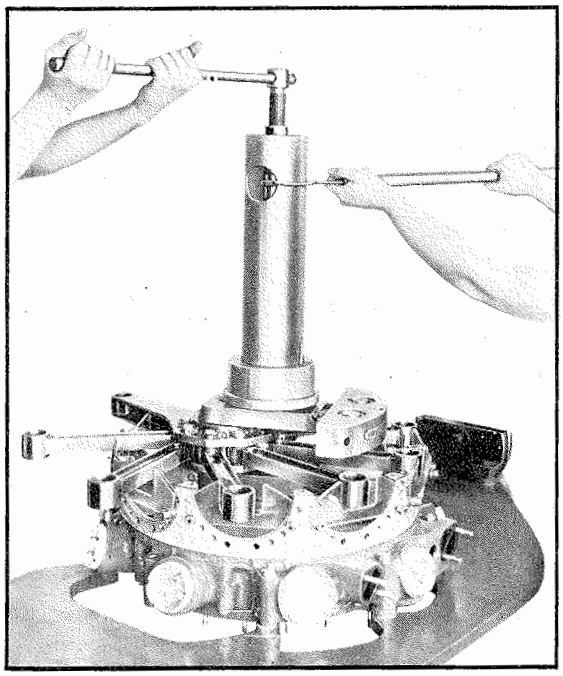


**Fig. 103. Removing Front Main Bearing Inner Race**

## CRANKSHAFT, MASTER ROD, AND ARTICULATED RODS

Install the crankshaft hoisting eye (Tool No. 82151) over the crankshaft front extension. Tighten the threaded end of the tool on the reduction driving gear nut threads on the crankshaft. Pass the hook on a chain hoist through the hoisting eye and lift the crankshaft and connecting rod assembly out of the crankcase rear main section. See figure 104. The crankshaft rear main bearing remains on the crankshaft, since the diameter of the rear main bearing nut is large enough to prevent the rollers and outer race from being demounted.

**CAUTION:** If any difficulty is experienced in removing the crankshaft, do not attempt to force the assembly out of the

crankcase. In some instances, the rear main bearing outer race is a tight fit in the bearing retainer thus preventing the easy removal of the crankshaft assembly from the crankcase. Any attempt to force the crankshaft free will result in damaging the rollers in the bearing. When this situation occurs proceed as follows: Break the lock wire and remove the 18 bolts and washers which retain the supercharger front housing and the crankcase rear main

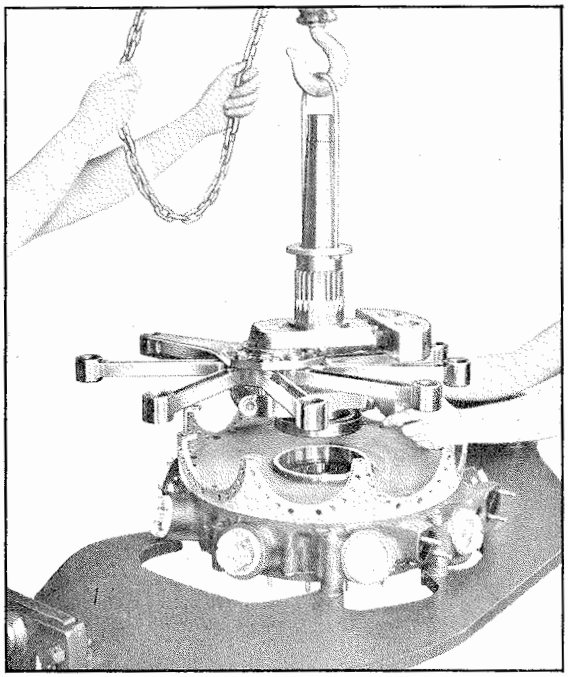


**Fig. 104. Removing Crankshaft and Articulated Rod Assembly**

section. Carefully raise the crankshaft assembly while supporting the crankcase rear main section. Place the crankshaft assembly in the holding fixture and secure it in position. Bend down the locking tab and remove the lock screw from the rear main bearing retainer nut. Remove the nut using lug wrench (Tool No. 80409). Remove the rear half of the crankcase main section from the crankshaft assembly. Remove the cage and rollers from the outside race in the crankcase rear main section, and tap the outer race from the bearing retainer. Reassemble the rear main bearing on the crankshaft rear section and reinstall the retainer nut prior to checking the crankshaft alignment.

It is recommended that the crankshaft assembly be checked for alignment before disassembly. Install the crankshaft and connecting rod assembly on two alignment checking rollers (Tool No. 82658), after removing the hoisting eye from the crankshaft. Hold the master rod in a vertical position and group four articulated rods on both sides of the master rod together, holding each group of rods together with a heavy rubber band. Turn the crankshaft on the rollers and using a dial indicator, check the run-out at the front and rear propeller shaft bushing journals on the crankshaft. See figure 105. The allowable

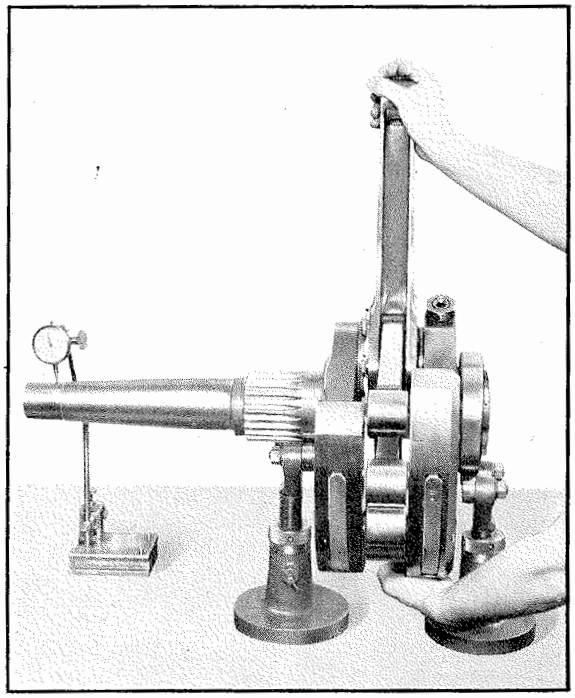


**Fig. 105. Check Run-Out of Front and Rear Propeller Shaft Bushings**

run-out at these locations is specified in the applicable Table of Limits. This check will indicate whether the crankshaft rear has slipped with relation to the crankpin during past engine operation due to improper clamping.

Install the crankshaft in the assembly and disassembly fixture (Tool No. 800710, mounted on floor stand, Tool No. 800711). Tighten the two clamps on the fixture to hold the crankshaft firmly in the fixture, with the counterweights in the downward position. Adjust the knurled head bolt underneath the crankshaft

rear counterweight to support the crankshaft during the following operations. Tighten the lock nut on the bolt to lock the bolt in the proper position. See figure 106.

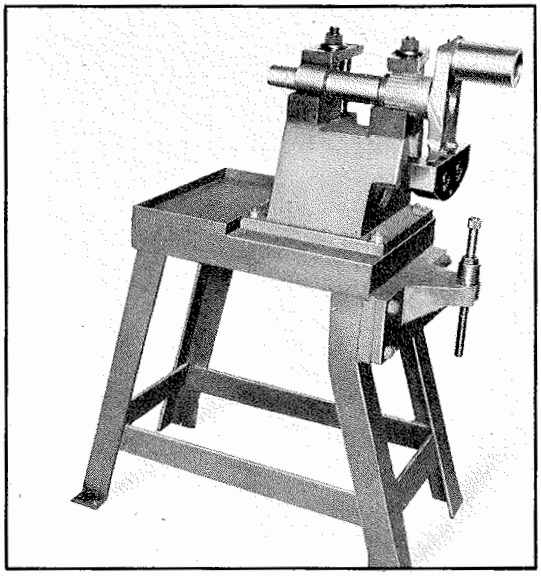


**Fig. 106. Crankshaft in Assembly Fixture**

Remove the accessory drive shaft coupling from the recess in the crankshaft rear using puller (Tool No. 801111). Some engines incorporate a coupling lock spring which must be removed before the accessory drive shaft coupling can be removed.

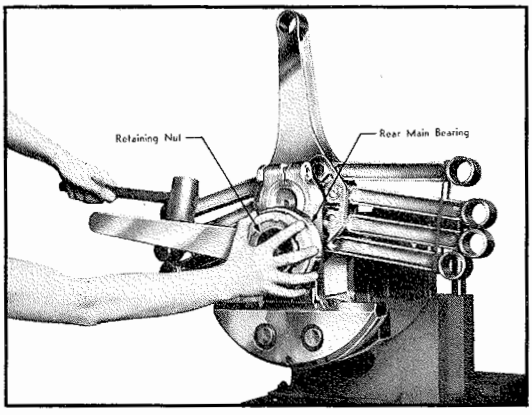



**Fig. 107. Loosening Crankshaft Rear Main Bearing Nut**

**CRANKSHAFT REAR MAIN BEARING** Remove the crankshaft rear main bearing nut lock screw and locking tab. Remove the nut using lug wrench (Tool No. 80409). See figure 107. Remove the rear main bearing outer race and rollers from the inner race. Install the crankshaft rear main bearing inner race puller (Tool No. 84559) and the four segments of the adapter (Tool

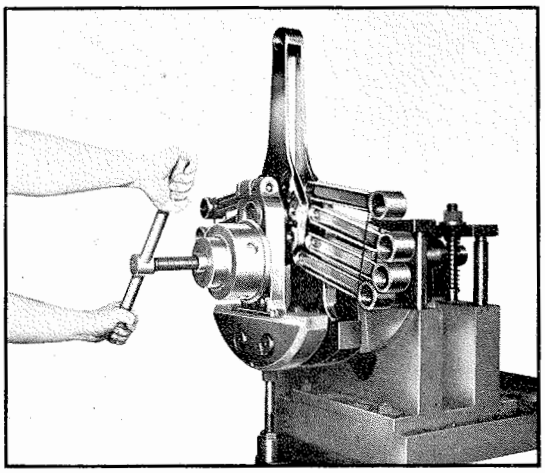


**Fig. 108. Removing Rear Main Bearing Inner Race**

No. 84561) on the bearing inner race, locking the tools in place on the race with the collar on the puller. Remove the race. See figure 108. Remove the puller and adapter. Wrap the rear main bearing inner race, outer race, and retainer and rollers together in oiled paper.

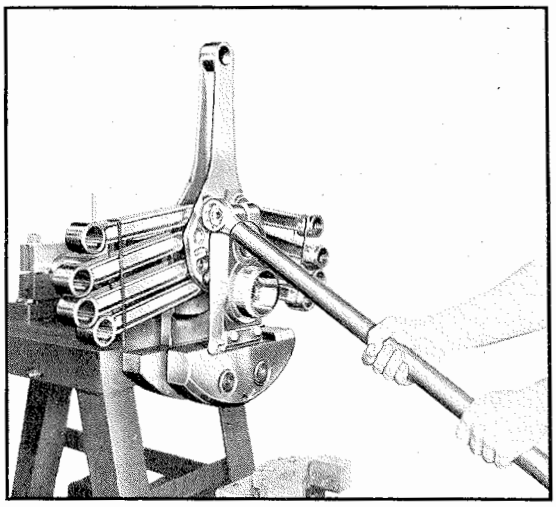


**Fig. 109. Loosening Crankcheek Cap Screw**

**CRANKSHAFT REAR END** Remove the cotter pin from the crankshaft rear end cap screw. Loosen the cap screw using wrench (Tool No. 80309) and extension (Tool No. 80198). See figure 109. Remove the cap screw and washer. Install the crankshaft rear spreader plug (Tool No. 84765-1) in the unthreaded end of the cap screw hole, and install the plate (Tool No. 84765-2) in the slot in the plug so that the plate contacts the side of the clamp joint. Tighten the screw (Tool No. 84699) in the threaded end of the cap screw hole to force the plate against the side of the clamp joint and spread the crankshaft rear. See figure 110. Do not spread the

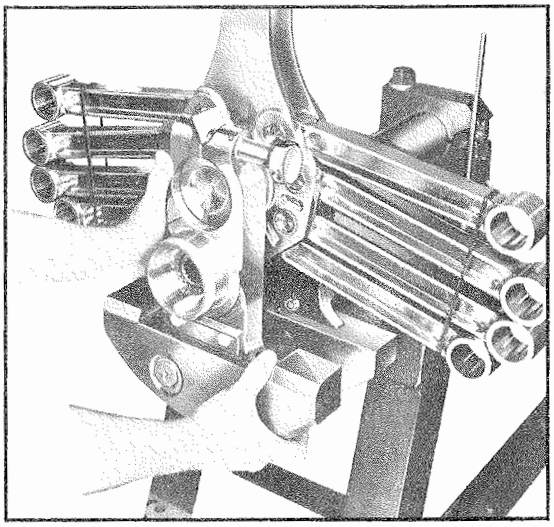


**Fig. 110. Removing Crankshaft Rear**

crankshaft rear any more than is necessary to permit removal of this part. Remove the crankshaft rear from the crankpin, and remove the spreading tools. Place parts in rack as shown in figure 111.

Remove the cotter pins locking the two nuts which secure the crankshaft rear counterweight stop to the crankshaft rear. Remove the nuts, bolts, and the stop. Line up the bushings in the crankshaft rear with the counterweight bushings and remove the counterweight pins. Remove the crankshaft rear from the counterweight. Remove the floating steel bushings from the crankshaft rear. Do not remove the bronze bushings from the crankshaft rear or the steel bushings from the counterweight unless replacement of these parts is necessary. Instructions for replacing these parts are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle CRANKSHAFT, MASTER ROD, AND ARTICULATED RODS.

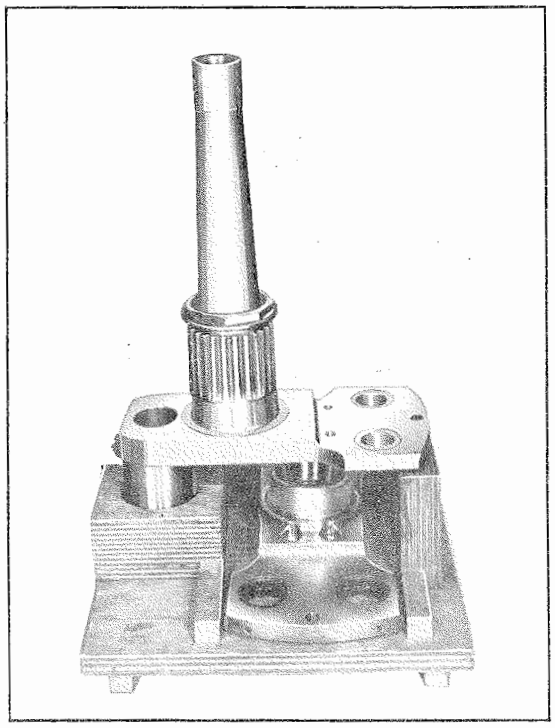


**Fig. 111. Crankshaft Rack**

**MASTER ROD AND ARTICULATED RODS** Remove the master rod end seal spacer. Check the rear end of the crankpin to insure that there are no nicks or burrs present which might scratch or score the master rod bearing upon removal of the master rod and articulated rod assembly. Remove any nicks or burrs in this location by stoning and polishing. Grasp the two groups of articulated rods, one on each side of the master rod, and remove the master rod and articulated rod assembly from the crankpin. See figure 112. Remove the end seal disk and spring.

Place the master rod and articulated rod assembly on a bench, rear end down. Bend down the knuckle pin lock screw tabs and remove the lock screws and tabs. Lift off the knuckle pin locking plate.

Place the knuckle pin assembly and disassembly fixture (Tool No. 83913-1 or Tool No.

800260) on an arbor press table. (Tool No. 83913 is a set of tools, and includes all tools necessary for removal and installation of knuckle pins. Tool No. 800260 is a fixture, used in connection with wedges, Tool No.

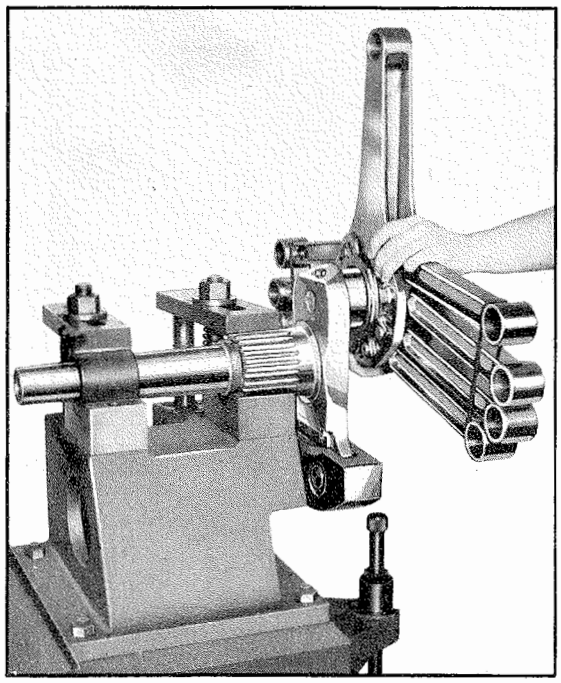


**Fig. 112. Removing or Installing Master and Articulated Rod Assembly**

800282, and plugs, Tool No. 800283, for performing the same operations.) Locate the knuckle pin to be removed over a hole in the fixture. Insert the two wedges (Tool No. 83913-19 or Tool No. 800282) between the flanges

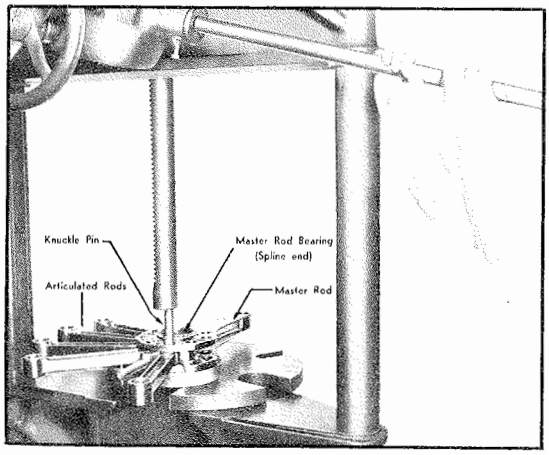



**Fig. 113. Pressing Out Knuckle Pin**

of the master rod, one on each side of the articulated rod to be removed, to prevent possible damage to the master rod flanges when pressing out the knuckle pin. Press out the knuckle pin using the removing plug (Tool No. 83913-20 or Tool No. 800283-2) under the arbor, fitting the step on the plug in the step in the knuckle pin. See figure 113. Re-

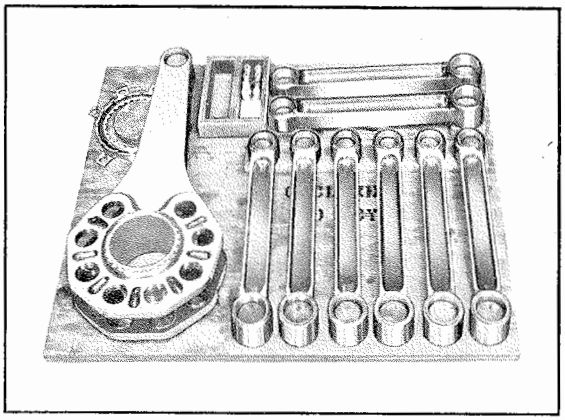


**Fig. 114. Master and Articulated Rods Rack**

move the knuckle pin and the articulated rod. Remove all remaining knuckle pins and articulated rods in the same manner, each time moving the wedges to the respective articulated rod. Place parts on rack as shown in figure 114. Do not remove the master rod bearing unless replacement of this part is found to be necessary. Do not remove the knuckle pin bushings or the piston pin bushings from the articulated rods unless replacement of these parts is necessary. Instructions for replacing the master rod bearing, knuckle pin bushings, and piston pin bushings are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle CRANKSHAFT, MASTER ROD, AND ARTICULATED RODS.

**CRANKSHAFT FRONT END** Remove the crankshaft breather tube rear support, if used, after bending down the locking tab and removing the lock screw and tab. Remove the crankshaft breather hole plug, which is used in place of the breather tube rear support in engines which employ a supercharger front housing breather, after bending down the locking tab and removing

the lock screw and tab. The plug may be removed by inserting a long fiber drift inside the crankshaft front extension and tapping with a fiber mallet.

Remove the crankshaft front end from the holding fixture. Remove the crankpin front plug after bending down the crankpin front plug lock screw tab and removing the lock screw and tab. Use puller (Tool No. 84512 or Tool No. 800477) to remove the plug. (Tool No. 84512 is designed for use with plugs provided with a tapped puller hole. Tool No. 800477 is designed for use with plugs having a slotted puller lip.) See figure 115.

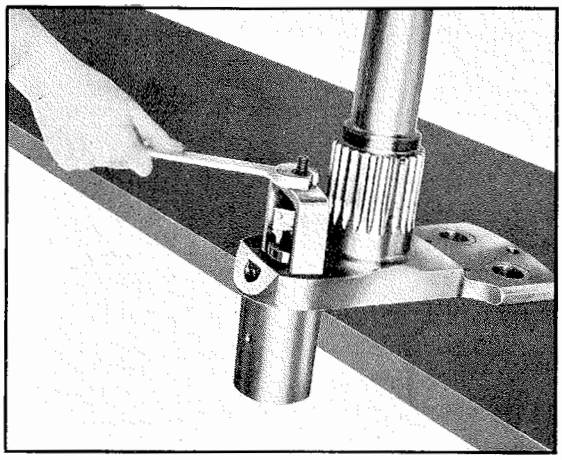


**Fig. 115. Removing Crankpin Front Plug**

Remove the crankshaft front counterweight stop, counterweight pins, and the counterweight from the crankshaft front end in the same manner as the corresponding parts were removed from the crankshaft rear. Do not remove the steel bushings from the crankshaft front end or from the counterweight unless replacement of these parts is found to be necessary. Instructions for replacing these parts are included in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES, under the subtitle CRANKSHAFT, MASTER ROD, AND ARTICULATED RODS.

## CRANKCASE REAR MAIN SECTION AND SUPERCHARGER FRONT HOUSING

The following operations should be accomplished with the mounting plate locked in a horizontal position, with the crankcase rear main section up.

Remove the lock wire from the 18 cap screws which secure the crankcase rear main section to the supercharger front housing. Remove the cap screws and washers.

Lift the rear main section off the supercharger front housing and install flange protectors (Tool No. 801789) on each parting surface of the main section.

**SUPERCHARGER FRONT HOUSING BREATHER** If it is necessary to replace the impeller shaft front oil seal support, remove the eight screws which secure the support to the web of the supercharger front housing. Remove the support, ring, and gasket. Remove the two palnuts, nuts, and washers which secure the supercharger front housing breather or substituting cover to the front housing. Remove the breather and screen or the cover and gasket.

Do not remove the supercharger front housing breather relief valve assembly from the front housing.

Remove all plugs from the supercharger front housing. Remove the intake pipe packing nut covers (Tool No. 800907) from the packing nuts. Remove the packing nuts and packing. Discard the packing.

Remove the supercharger front housing from the engine assembly and disassembly stand.

## CHAPTER III

# CLEANING OF ENGINE PARTS

**GENERAL PROCEDURE** The cleaning of engine parts consists essentially of three operations: first, the removal of heavy oil, grease, and sludge by washing or by using a degreasing machine; second, the softening of carbon deposits by immersion in a heated bath of cleaning solution; and third, the removal of hard carbon deposits by brushing, scraping, or gritblasting. Gritblasting is only done on cylinder heads, valves, and inside of pistons. The preliminary washing of parts before immersing in the carbon softening bath is necessary in order that the cleaning solution will not be contaminated with oil and sludge. The softening of carbon deposits before removal is essential in order that these deposits may be subsequently removed with a minimum of difficulty.

**MAGNESIUM PARTS** Magnesium parts should be washed only with gasoline or kerosene. Gasoline used for cleaning engine parts should be a good grade of ordinary motor gasoline to which no detonation inhibitors or coloring matter have been added. The cleaning of engine parts of all materials may be accomplished by spraying with gasoline or kerosene. However, due to the inflammability and expense of these cleaning agents, and the necessity of treating the parts after cleaning to prevent rusting, operators largely prefer to use other cleaning mediums.

**MASTER ROD BEARINGS** Master rod bearings should only be cleaned by wiping with a clean cloth soaked in unleaded fuel. Do not attempt to clean used master rod bearings by any other means, such as brushing, polishing, burnishing, or subjecting to the action of any cleaning solution other than unleaded fuel. Install plugs in the oil holes and protectors (Tool No. 800924) on the master rod at the ends of the bearing when immersing the master rod in the tank to prevent the cleaning solution from coming in contact with the bearing. See figure 116.

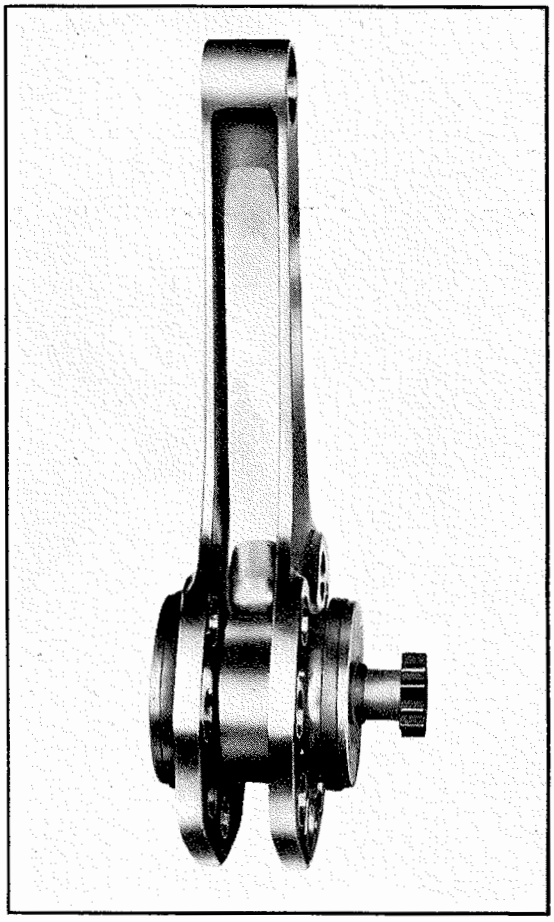


**Fig. 116. Master Rod Prepared for Cleaning**

**WASHING** A large variety of cleaning preparations is available, but operators are urged to exercise extreme caution in using unfamiliar cleaning solutions or compounds since damage to engine parts, par-

ticularly aluminum parts, may result from the use of inferior preparations.

Some water-mixed cleaning solutions have been found unsatisfactory for the reason that any traces of such solutions containing soap compounds or caustic soda, which may remain impregnated in the pores of the metal and become mixed with the oil during operation of the engine, might result in oil foaming. In the case of alkaline cleaners, the alkaline compounds may combine with the oil in the presence of acids which come from combustive gases normally present in the oil, and form soap which produces oil foaming.

Engine parts may be satisfactorily washed using Stoddard Solvent (Varsol or Ultrasene) and hot water heated to 190-200 deg. F.

**SOFTENING CARBON DEPOSITS** Two types of tanks are used to contain the cleaning solution bath when softening carbon deposits on engine parts. An open tank (Tool No. 801075) heated by means of a steam coil, is used for all engine parts except magnesium parts and pistons. See figure 117. Carbon deposits may be satisfactorily softened using Gunk or Gerlach No. 70 stripper, if available, heated to 80-100 deg. F. The temperature should not exceed 110 deg. F. in this type of tank. Instructions for procuring and mixing Gunk or Gerlach No. 70 stripper are included in the section in the Appendix entitled SHOP MATERIALS.

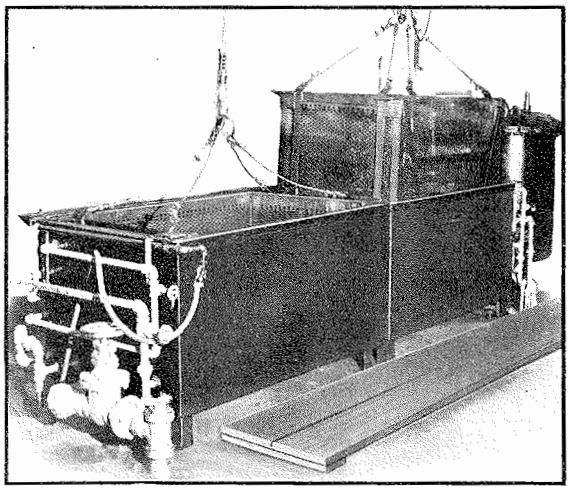


**Fig. 117. Parts Washing Machine**

The open type tank, including parts holding baskets, heating coils, temperature control, and exhaust system, may be procured under Tool No. 801075. The average time required to strip paint and soften carbon deposits, using this equipment and cleaner is approximately two hours, but may vary according to the condition of the part.

A closed, pressure-type tank (Tool No. 801674) is used for softening hard carbon deposits on pistons, and on any parts which do not respond to the Gunk treatment in the open tank. See figure 118. Gerlach No. 99 cleaner or equivalent, heated to 260-280 deg. F. under a pressure of 30 to 40 lb. per sq. in. may be satisfactorily used in this type of tank. Instructions for procuring and mixing Gerlach No. 99 cleaner, or equivalent, are included in the Appendix entitled SHOP MATERIALS. Immerse the parts in the cleaning solution in the

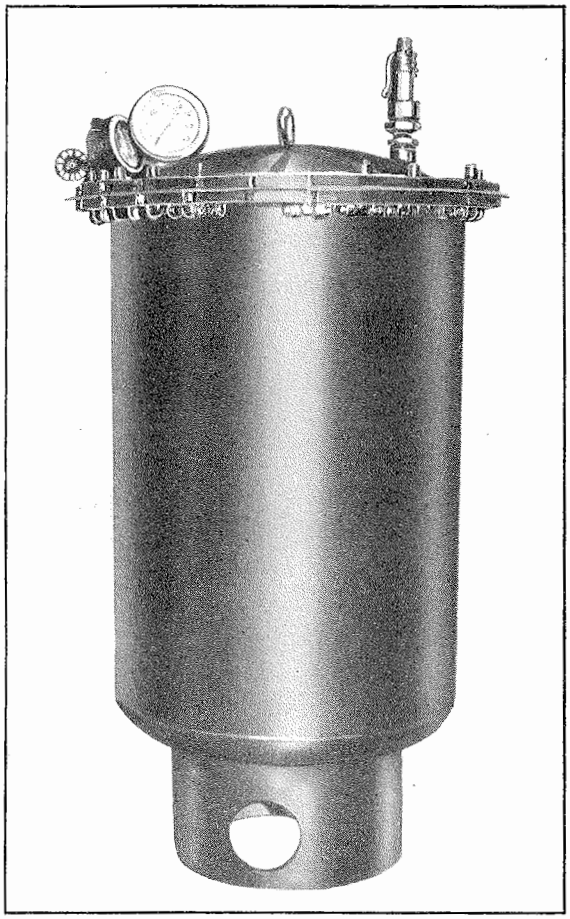


**Fig. 118. Pressure Cleaning Tank**

tank. Close and secure the cover of the tank. Introduce steam into the heating coil until a pressure of 30 to 40 lb. per sq. in. has been built up in the tank. Maintain this pressure for two hours. At the end of this time, turn off the steam. Circulate cooling water through the coil until the temperature of the bath is reduced approximately 100 deg. F. or zero pressure is reached. Open the tank and remove the engine parts. Put the parts in a bath of Stoddard Solvent (Varsol or Ultrasene). The pressure type tank may be procured under Tool No. 801674.

**REMOVING HARD CARBON DEPOSITS** Remove the deposits of carbon after softening by brushing, scraping, or gritblasting, depending upon the hardness of the carbon deposit and the effectiveness of the softening operation. This final operation should be accomplished immediately after removing the parts from the Stoddard Solvent (Varsol or Ultrasene) bath.

Remove as much carbon as possible by hand brushing, using a stiff bristle brush. In the case of pistons, approximately 75% of the carbon deposits on the exterior surfaces of a piston may be removed by brushing, but some carbon may still adhere to the two upper ring grooves.

Carbon which may not be removed by hand brushing may be removed by scraping. Extreme care should be exercised to avoid scratching or gouging engine parts when scraping. Light scraper marks, if found, should be removed by polishing with crocus cloth and gasoline. After brushing and scraping a piston, install the piston in the holding fixture (Tool No. 801830) and install the fixture and piston in a polishing lathe. Polish the bearing surfaces, ring grooves, and top of the piston smooth using crocus cloth and gasoline.

Removal of carbon from piston ring grooves should be accomplished very carefully so as not to remove the small radii at the bottom of each ring groove. Use a suitable hand scraper (Tool No. 84524) with the sharp corners stoned off so as to preserve the radii in the bottom of the groove. Place a tool rest on the lathe to support the scraper. See figure 119. Clean the carbon from the oil drain holes in the ring grooves. This may be accomplished by using a suitable drill held in a tap handle, being careful not to enlarge or scratch the hole.

Hard carbon and tetraethyl lead deposits or other foreign material may readily accumulate in the joint between the cylinder head and the top of the cylinder sleeve. A rotating wire brush used on the end of a flexible shaft

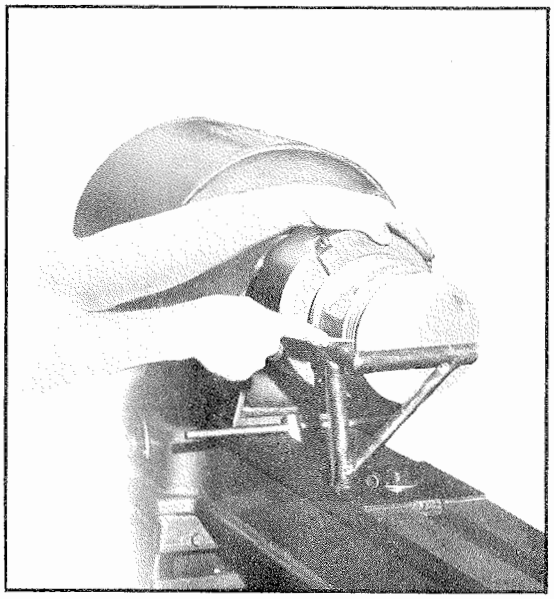


**Fig. 119. Removing Carbon from Piston Ring Grooves**

can be used to do this work. However, extreme care should be exercised not to contact the sides of the cylinder barrel with the rotating brush.

Abrasive cleaning, or gritblasting, is recommended for removing hard carbon deposits from the interior portions of pistons and cylinder heads, and for removing paint from and cleaning exterior surfaces of engine parts prior to repainting. This type of cleaning removes hard carbon deposits and paint rapidly and easily from surfaces difficult to clean in any other manner. Caution must be exercised, however, to prevent damage to engine parts when performing this cleaning. The use of harmful abrasives, or the use of excessive air pressure, or failure to protect machined surfaces properly when cleaning may result in

damage to engine parts which might render those parts unsatisfactory for use.

Sand and carborundum grit have proven to be satisfactory materials for abrasive cleaning of engine parts. Crushed shot is unsuitable for this type of cleaning because of the tendency of particles of this material to become imbedded in the metal parts being cleaned.

When grit-blasting, protect machined surfaces with suitable plugs, sleeves, or friction tape so that these surfaces will not be damaged. Prepare a piston for gritblasting as follows: From the inside of the piston, insert a tapered rubber, wood or fiber plug in each piston pin hole to protect the finished surfaces. Place two pistons with heads together in the rubber holding fixture (Tool No. 802270) and proceed with the gritblasting operation.

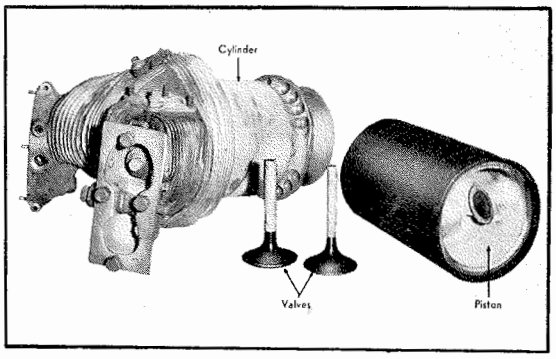



**Fig. 120. Cylinder, Pistons, and Valves Prepared for Sand Blasting**

Prepare a cylinder for gritblasting the carbon from the combustion chamber by installing the cylinder wall protector sleeve (Tool No. 802270) in the cylinder. Install a dummy spark plug and washer in each spark plug insert to protect the inner threads and outer face of the insert. Protect the skirt and flange of the cylinder with a suitable sleeve. See figure 120.

To gritblast the hard carbon or tetraethyl lead deposits from exhaust valve heads, cover the valve stem with masking tape and gritblast the valve head. Use the same procedure for intake valves. Do not gritblast any part of the valve stem during this operation. Do not gritblast valves which are not going to be refaced. Wash parts thoroughly in Varsol or Ultrasene to remove any abrasives.

The use of excessive air pressure increases the tendency of the abrasive to become imbedded in the metal parts being cleaned. Use only a pressure high enough to remove hard carbon deposits from parts being cleaned. The required pressure depends upon the degree of hardness and amount of carbon to be removed. Adjust the pressure first to 30 lb. per sq. in. If this pressure will not remove the carbon satisfactorily, increase the pressure in increments of 5 lb. per sq. in., checking the effectiveness of the gritblasting operation each time, until a pressure is reached which removed the carbon effectively.

Antifriction bearings may be washed and cleaned the same as other engine parts, but be sure that they are washed separately in order that no particles of dirt become lodged within the races. If the bearing is to be installed in the engine immediately, lubricate the balls or rollers and races and reinstall it. If the bearing is not to be installed immediately, immerse it in Anticorrosion Compound, W.A.C. Spec. No. 5842C or equivalent, wrap it in oiled paper, and keep it in a clean dry place until ready for use.

A gasoline spray may be used for cleaning antifriction bearings also. While spraying, hold the races to prevent spinning the bearing. Dry and oil the bearing after cleaning in order to prevent corrosion.

It is the practice in many places to keep a container of kerosene or gasoline for cleaning miscellaneous parts. Such receptacles must never be used for washing antifriction bearings as metal chips or dirt are almost certain to be introduced into the bearing.

CHAPTER IV

# INSPECTION OF ENGINE PARTS

THE inspection of engine parts should be accomplished in accordance with instructions in this chapter, in connection with the INSPECTION FORMS included in the section in the Appendix entitled SERVICE STATION MANAGEMENT AND ROUTINE FORMS. Instructions in the text of this chapter follow closely the INSPECTION FORMS outline. The inspector should record the condition of each part on the forms, and include recommendations regarding the repair or disposition of each part.

Instructions covering the inspection of gaskets, packing, hoses, circlets, piston pin retainers, piston rings, oil seal rings, and ignition wire cable are intentionally omitted from this chapter. The Wright Aeronautical Corporation recommends that these parts be replaced with new parts at every overhaul. Instructions covering the inspection of paint and enamel on engine parts are not included inasmuch as the repair of parts by painting is not a compulsory operation, but depends entirely upon the judgment of the operator.

## MAGNETIC TYPE INSPECTION

**NEED FOR MAGNETIC TYPE OF INSPECTION** Subsurface cracks and nonmetallic inclusions are impossible to detect by visual inspection alone. Due to the natural permeability of iron and steel, almost all engine parts fabricated of these materials lend themselves to what is known as the magnetic type of inspection. By this method of inspection, the aforementioned type of flaws may be located. This section will deal with defects of this nature and their detection by the magnetic type of inspection. The section is designed to present in convenient form, a procedure which the overhaul operator may use safely in inspecting Wright engine parts, and enough information to enable him to understand the procedure.

**EQUIPMENT FOR MAGNETIZATION AND DEMAGNETIZATION OF ENGINE PARTS** Special equipment is required to magnetize properly engine parts to be inspected by the magnetic type of inspection. Wherever equipment is available it is recommended that the operator use this method of inspection on appropriate parts in overhaul work. Patented machines, designed for magnetizing and demagnetizing parts, are on the market in a variety of sizes and models. Tanks, inspection benches, and other accessories are also available. Specific information regarding equipment should be sought from the company by which the equipment is manufactured. Any descriptive references made to equipment in this section are made only in connection with the inspection of engine parts. No attempt will be made to explain the installation, operation, and maintenance of the equipment.

For the average overhaul base the standard Army-Navy unit, equipped with a coil, is recommended as the most practical and the most adaptable all-purpose unit for conditioning parts for the magnetic type of inspection. This unit operates on 110 volt alternating current and delivers direct current from a battery source to the part being inspected. A separate unit is required for the demagnetization of parts in conjunction with the standard Army-Navy unit.

For the small overhaul base, or where economy is essential, an appropriate unit is available, operating on alternating current. No special demagnetizing apparatus is necessary if this unit is employed.

**PRINCIPLES OF THE MAGNETIC TYPE OF INSPECTION** The magnetic type of inspection may be described as the interpretation of the effects of the following phenomena:

1. At sudden interruptions in the path of magnetic fields flowing through a specimen, the direction of the lines of force is deflected, resulting in what are known as "local leakage fields."

2. If small particles, having satisfactory magnetic properties, are brought into the vicinity of these leakage fields, the particles will be attracted to and held by such fields.

Flaws such as nonmetallic inclusions or cracks, surface or subsurface, in a magnetized part will cause local leakage fields. See figures 121 and 122. Minute particles of iron oxide, when applied to the part, will adhere to such vicinities. By the patterns so formed the inspector can determine the shape and extent of the defect.

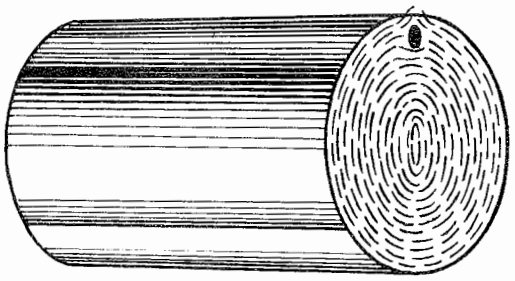


**Fig. 121. Sketch Showing Sub Surface Defect**

The proper use of the magnetic-type inspection method and the correct interpretation of the results of its application are of utmost importance. An error in one or the other or both of these operations may result in wasteful scrapping of valuable material or in the ultimate failure of defective parts.

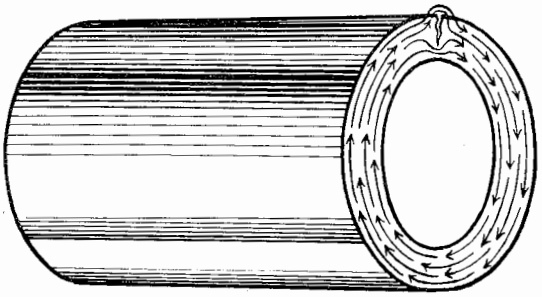


**Fig. 122. Sketch Showing Surface Crack**

**MAGNETIZATION OF PARTS** Magnetic fields may be effected in parts subject to magnetization in one or another of the following ways:

1. The part may be placed directly between two copper contact plates and a current run through the part. See figure 123.

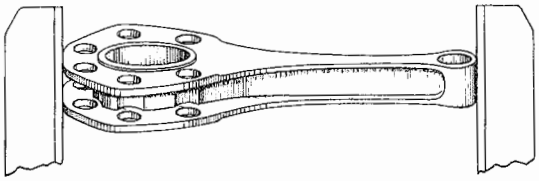


**Fig. 123. Master Rod Between Copper Contact Plates**

2. Parts may be mounted on a copper conductor, the conductor placed between two copper contact plates, and a current run through the conductor. See figure 124.

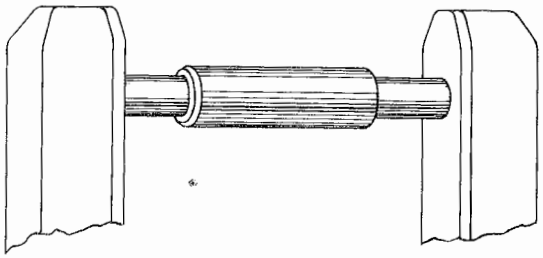


**Fig. 124. Piston Pin on Copper Conductor Bar**

3. A part may be placed in the magnetic field induced by a coiled conductor (usually the coil in the machine). See figure 125.

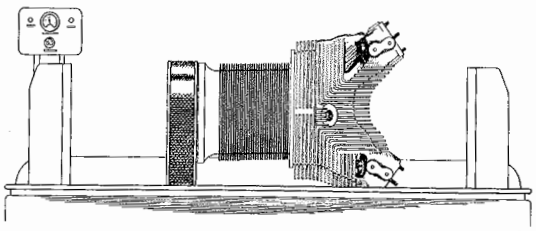


**Fig. 125. Cylinder Skirt in Coiled Conductor**

Different facilities are provided in different units for performing these operations, but the basic processes are the same.

A flaw in a magnetized part is most ef-

fectively disclosed by applying iron oxide particles to the part when the magnetic lines of force cross the direction of the defect at right angles. For this reason certain parts must be magnetized in more than one way. The direction in which the magnetic lines of force are to be effected should be governed according to the defects which are suspected to be present, according to the stresses to which the parts are subjected and with a view to defects which may be the result of mishandling of the parts. Refer to the applicable paragraphs under the heading of PARTS REQUIRING SPECIAL ATTENTION and to the table at the end of this section for the selection of the method of magnetization of parts.

In order to determine how to place a part in the unit to effect a given direction of magnetic lines of force it may be helpful if the operator will remember the popular "rule of thumb." Hold the thumb of the right hand rigidly in the direction in which the current is applied to a part and let the fingers of the hand fall loosely. The direction of the curving fingers will indicate the direction of the magnetic lines of force produced in the part. See figure 126. This method of magnetization, as produced in (1) and (2) above, is termed the circular method, the word "circular" designating the direction of the lines of force in the magnetized part.

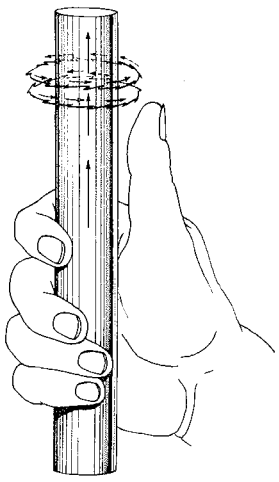


**Fig. 126. Sketching Showing "Rule of Thumb"**

Referring again to the "rule of thumb"—if the current is applied in the direction of the fingers, as in (3) above, the lines of force will be induced in the part in the direction of the thumb. This method of magnetization, as produced in (3) above, is termed the longitudinal method, the word "longitudinal" designating the direction of the lines of force in the magnetized part.

**APPLICATION OF IRON OXIDE TO MAGNETIZED PARTS** Iron oxide particles may be applied to a magnetized part in one of the following ways:

1. In a dry powdered form (dry method)
2. Suspended in a solution of Varsol or Ultrasene (wet method)

The latter, or wet method, has proved to be the more successful of the two, and is therefore recommended whenever feasible.

The suspensoid containing the iron oxide particles may be applied to magnetized parts in one of the following ways:

1. It may be applied as a bath or by hose after the part has been magnetized (residual method). See figure 127.

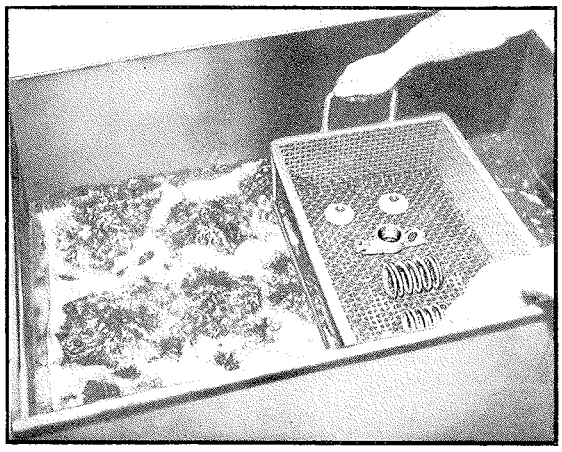


**Fig. 127. Applying Iron Oxide Particles (Residual Method)**

2. It may be applied as a bath or by hose while the part is being magnetized (continuous flow method). See figure 128.

The residual method utilizes only the residual magnetic field existing in the part after the current has been shut off. After the part has been charged, the fluid should be applied as in (1) above. When applying the continu-

ous flow method, the entire part must be wet with the solution containing the iron oxide particles before and during the application of

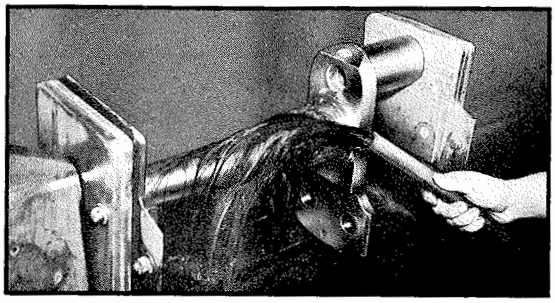


**Fig. 128. Applying Iron Oxide Particles to Crankshaft with Hose (Continuous Flow Method)**

current. In this continuous flow method, particles will be attracted to local leakage fields at the peak of flux density in the part. The operator must bear in mind that the same amperage, applied to a part, will attract heavier deposits of iron oxide if the continuous flow method is employed than if the residual method is employed.

**RECOMMENDATIONS FOR THE SUSPENSION** Various preparations of iron oxide are on the market. Black iron oxide powder is recommended for use in a solution of Varsol or Ultrasene for detecting defects in magnetized engine parts. In cases where parts are discolored, a red iron oxide powder may be used in place of the black.

It is important to keep the suspension uniform. A proportion of one ounce of iron oxide powder to one gallon of Varsol is recommended. The fluid should be constantly agitated to prevent settling of the iron oxide particles. The suspension should not be used for more than eight hours without being tested for uniformity. If a hose is being used, the test sample should be taken from the hose.

To test the suspension, fill a 100 c.c. graduate tube and allow the particles to settle. Place the tube in a demagnetizing unit, disturbing it as little as possible, but holding it close to one wall of the unit. Remove the tube slowly from the unit, and allow it to stand for thirty minutes. If, at the end of this time, the powder at the bottom of the tube reaches the 1½ c.c. mark and does not exceed the 2 c.c. mark, the proportion of iron oxide to liquid is satisfactory. If the test is not within these limits, the suspension should be readjusted to meet the necessary requirements.

**INSPECTION OF PARTS** Parts should be inspected immediately after the application of iron oxide particles. Adequate lighting is essential for proper examination of the parts, and frequently a magnifying glass may be required. All surfaces must be scrutinized for indications of defects. The operator should, however, take into consideration the type of magnetization used before passing judgment on any iron oxide patterns which appear doubtful to him. Refer to the applicable paragraphs under the headings of PRINCIPLES OF THE MAGNETIC TYPE OF INSPECTION, MAGNETIZATION OF PARTS and DOUBTFUL INDICATIONS.

**DEMAGNETIZATION OF PARTS** Parts should be demagnetized after inspection or before being remagnetized for checking. To achieve this, place the part in the demagnetizing unit and turn on the current. Turn the part at random inside the demagnetizer and close to at least one wall of the unit, to insure destroying the field induced in the part for its inspection. See figure 129. Remove the part slowly from the demagnetizer, leaving the current on. When the part is approximately 18 inches from the demagnetizer, the current may be shut off. To test for demagnetization, hold a compass approximately six inches from the part to be tested. If the deflection of the needle does not exceed three degrees, the part may be considered satisfactorily demagnetized.

**DOUBTFUL INDICATIONS** The operator will sometimes find, when using a high amperage in the continuous flow method, that deposits appear in the direction of the grain flow lines of the metal. Other questionable indications may occur, due to other reasons. An irregularly shaped part will attain a saturation point in its thinner sections sooner than in its thicker sections, and will attract heavy deposits in these areas before flaws will be indicated in the thicker

areas. Parts which have been permitted to come in contact with a ferrous object during the process of magnetization will also attract deposits in the areas of contact.

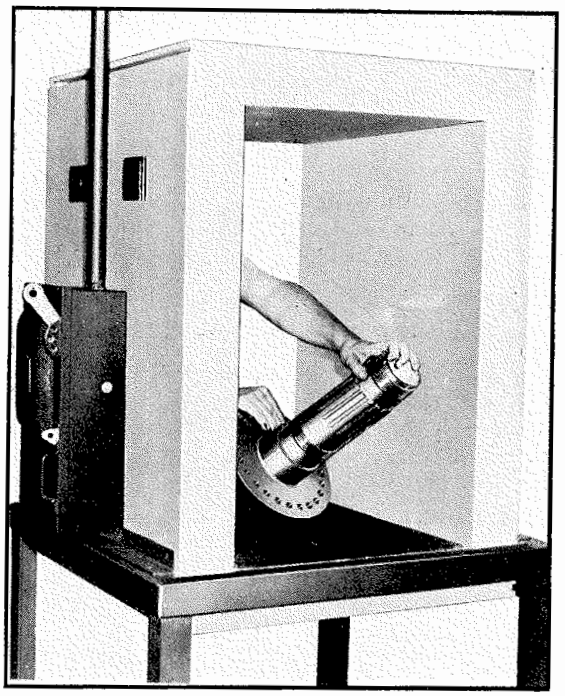


**Fig. 129. Demagnetizing Part After Magnetic Type Inspection**

**CHECKING DOUBTFUL INDICATIONS** Any doubtful indications should be checked. If the continuous flow method was used, mark the area to be checked. Demagnetize the part. Remagnetize and test the part by the residual method. If a dangerous flaw is present, it will reappear, possibly not so heavily marked, but in the same orientation and to the same extent. This will also be true if the part is demagnetized, remagnetized, and tested by the continuous flow method again, reducing the application of current to approximately one-half the amperage originally applied.

If the residual method was used, the part may be wiped and then examined with a magnifying glass. If still no defect is detected, demagnetize the part, remagnetize and recheck it either by the residual method, or by the continuous flow method at one-half the amperage previously used. A serious flaw will reappear in the same manner as described above.

**DISPOSITION OF PARTS** Any part found to be seriously defective should be rejected. In most cases, however, experience is the only means of determining the seriousness of flaws which are indicated by the magnetic type of inspection. With certain exceptions, therefore, the standards governing the disposition of parts must be left to the discretion of the Inspection Department. If, after checking by one of the above methods, any indications are found on the end face, on the pitch diameter, or at the root of any gear tooth, this is sufficient cause for rejecting the part. Splined parts should also be rejected in the case of similar indications with the exception of propeller shaft splines where slight indications on the tops of the splines are not dangerous. Indications at corners, steps, or radii of any part which, after magnetic inspection and removal of magnetic powder, can still be seen with the naked eye or with the aid of a small magnifying glass, are cause for rejection of the part. When the operator decides to use a part which has some slight indication, it is well to keep a record of that indication for future reference at the next overhaul. This may be done by applying a piece of transparent scotch tape to the part to pick up the pattern of the indication, removing the tape and pasting it on a suitable card. This operation transfers the pattern from the specimen to the paper. In this way the progress of the flaw may be observed at a future date. If any further question arises concerning disposition of parts, the parts should be returned to the Wright Aeronautical Corporation, Service Division, Paterson, N. J., with the history of the part attached.

**PRECAUTIONS**

(1) All parts being magnetized for inspection must first be thoroughly cleaned.

(2) All parts should be completely disassembled before magnetization with the exception of those specifically mentioned in the paragraphs on PARTS REQUIRING SPECIAL ATTENTION and in the table at the end of this section.

(3) Any passages which might trap the solution should be blocked with Vaseline. Passages thus blocked should be freed and

checked for clearness after the part has passed inspection and has been demagnetized.

(4) In order to avoid the possibility of arcing when applying current, the operator should be careful to see that the contacts are clean and tight. Lead plates covering the contact plates are effective for keeping the parts from being injured, but the lead must not be allowed to become too mutiliated or faulty contacts will result and this may lead to arcing or burning. The part should be held in position until the ammeter registers zero.

(5) All parts must be demagnetized after inspection.

(6) All parts must be cleaned and suitably slushed after demagnetization.

(7) Do not magnetize antifriction bearings unless specifically directed. It is too difficult to remove all the iron oxide particles from these bearings and any residual particles would have a damaging abrasive effect if the part should be put into operation. As antifriction bearings have a tendency to become magnetized in operation, it is recommended that these parts be demagnetized before reinstallation. After demagnetizing a bearing, clean it carefully according to instructions and wrap it in oiled paper until time for use. Rocker arm bearings may be left assembled, if properly protected. For further information on bearings, refer to the section on ANTIFRICTION BEARINGS in this manual.

(8) When parts are mounted on a conductor they should not touch the contact plates or each other. Parts should be sufficiently separated to permit the solution to come in contact with all surfaces. No ferrous material should touch a part during the process of magnetic inspection.

**PARTS REQUIRING SPECIAL ATTENTION** The following parts should receive special attention, using the continuous flow method. When the use of copper tubes or rods is recommended, their outside diameters should fit as far as practicable the inside diameters of the parts with which they are used.

(1) **Articulated Rods:** Magnetize these parts in three directions.

(a) Pass the current directly through the part from end to end at 1500 amperes.

(b) Place a copper rod through the knuckle pin end of the rod and pass 1500 amperes through the copper rod. (Copper rod to be 15 inches long.) Five articulated rods may be magnetized at one time.

(c) Place a copper rod through the piston pin end of the rod, using the same procedure as in (b).

(2) **Master Rods:** Magnetize these parts in three directions.

(a) Pass the current directly through the part from end to end using 2500 to 3000 amperes. See figure 130.

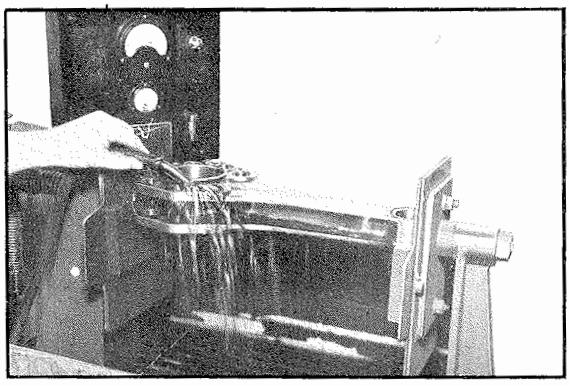


**Fig. 130. Passing Current Through Master Rod—End to End**

(b) Place a copper tube through the crankpin bore and pass 2500 to 3000 amperes through the tube. See figure 131.

(c) Place a copper tube through the piston pin bore and pass 2500 to 3000 amperes through the tube. See figure 132.

(3) **Crankshaft Front and Rear Sections:** Magnetize these sections in one direction through each individual section from end to end with the grain flow of the metal at 2500 to 3000 amperes.

(4) **Propeller Shafts:** Magnetize propeller shafts in a similar manner to that used for crankshafts, using 2500 to 3000 amperes. See figure 133.

(5) **Crankcase Front and Rear Main Sections:** Magnetize crankcases by placing a copper tube through the center of the case and by passing 2500 to 3000 amperes through the copper tube. Since it is usually impractical to use a copper bar large enough to fit the inside diameter of the crankcase sections, it is advisable to repeat the process of inspection three times, turning the crank case 90 degrees on the bar each time. If a tank is available, it is more expedient to submerge the crankcase section in the bath and pass the current through it.

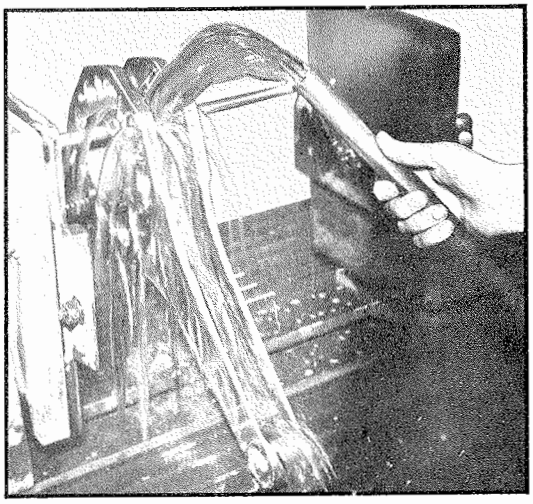


**Fig. 131. Copper Tube Through Master Rod Crankpin Bore**

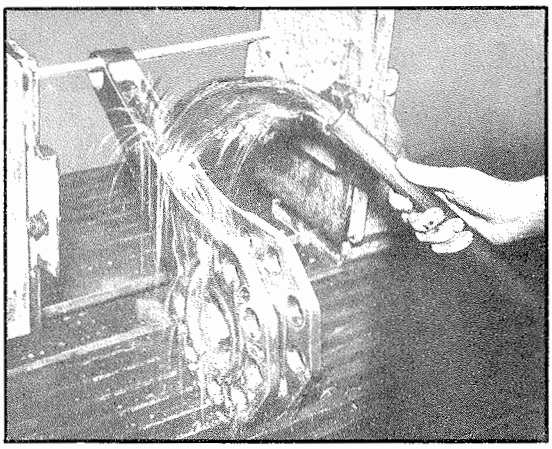


**Fig. 132. Copper Tube Through Master Rod Piston Pin Bore**

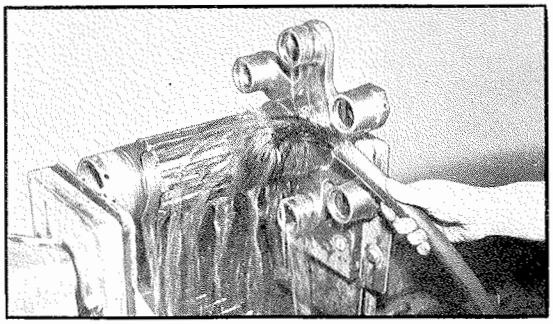


**Fig. 133. Magnetizing Propeller Shaft—End to End**

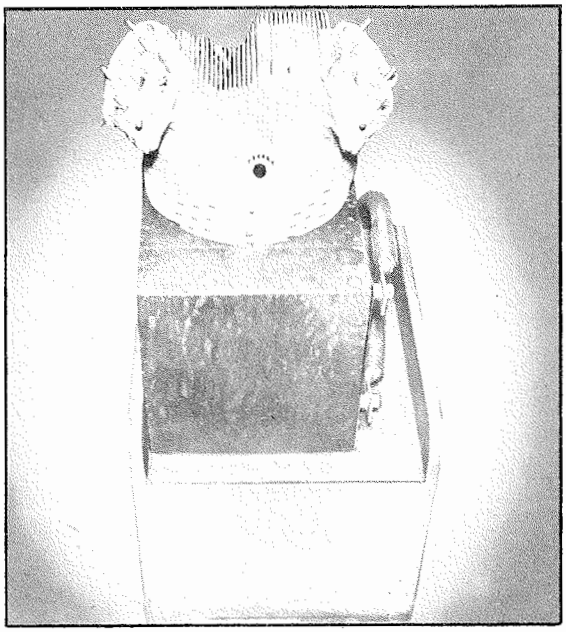


**Fig. 134. Magnetizing Cylinder Barrel in Coil**

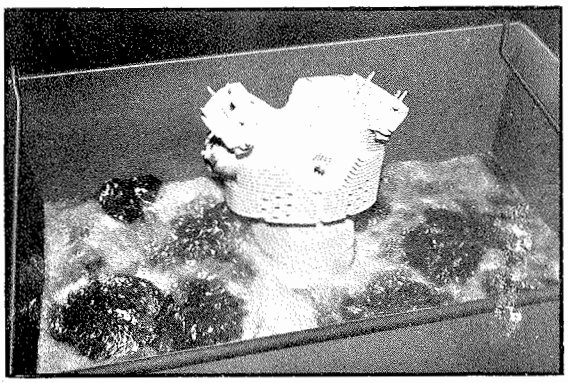


**Fig. 135. Applying Iron Oxide Particles to Cylinder Barrel in Bath**

(6) **Cylinders:** Magnetize cylinders in the coil, using 1000 amperes. See figures 134, 135, 136, and 137 for complete process.

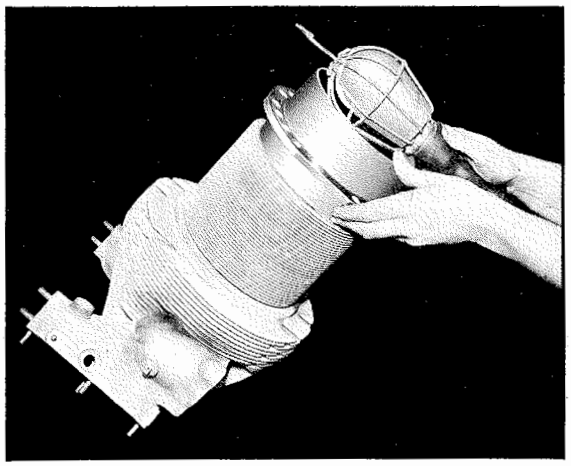


**Fig. 136. Visually Inspecting Cylinder Barrel for Defects**

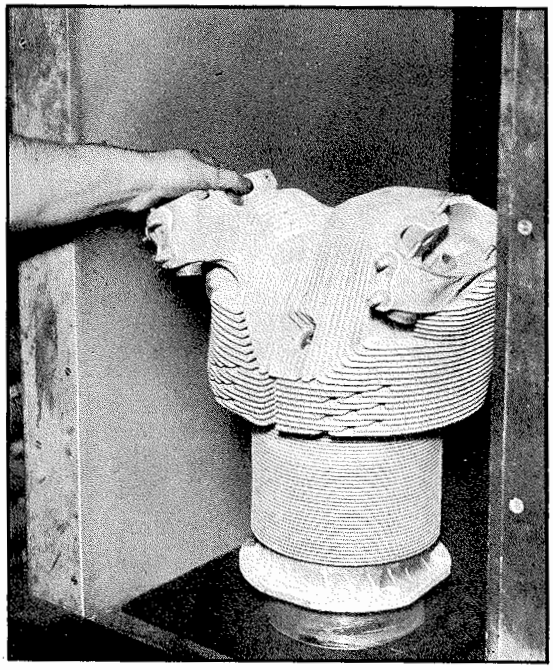


**Fig. 137. Demagnetizing Cylinder**

| Part |
|---|
| Accessory Drive Gear & Coupling |
| Accessory Drive & Starter Shaft |
| Articulated Rod |
| Ball Socket |
| Crankcase |
| Crankshaft Cap Screw |
| Counterweight Pin |
| Counterweight Bolt |
| Cam |
| Cam Drive Gear |

(7) **Valves and Valve Springs:** Magnetize these parts in one direction by passing the current directly through the part. Exhaust valves are not inspected by the magnetic method except when tip defects are suspected. For intake valves use 800 to 1000 amperes; for valve springs, use 300 amperes.

(8) **Rocker Arms:** Magnetize these parts in one direction by passing a current directly through the parts, using 1000 amperes. See figure 138.

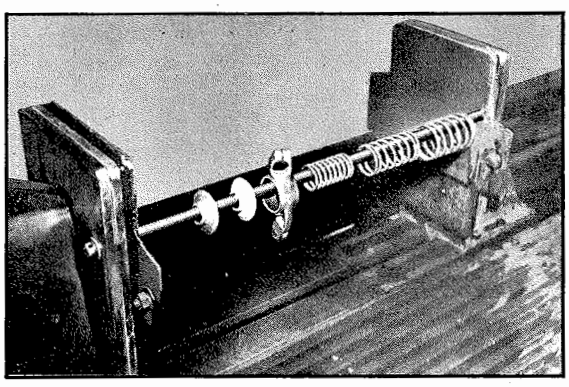


**Fig. 138. Magnetizing Rocker Arms, Valve Washers, and Valve Springs**

The following table has been prepared for use in conjunction with the preceding paragraphs in order to enable the operator to eliminate error in the procedure for inspecting specific engine parts. Any parts not listed, which are appropriate parts for the magnetic type inspection, should be classified by the operator according to the general instructions given herein. When the table specifies that a part should be magnetized in two ways, refer to the note at the end of the table.

| Method | Amperage |
|---|---|
| Residual—two ways | 2000 |
| Residual | 2000 |
| See applicable paragraph above | |
| Residual | 800-1000 |
| See applicable paragraph above | |
| Residual | 1500 |
| Residual | 1500 |
| Residual | 1000 |
| Residual—across outside diameter | 2000 |
| Residual—two ways | 1500 |

| Part | Method | Amperage |
|---|---|---|
| Oil Pump Drive Gear | Residual—two ways | 2000 |
| Cylinder | Continuous flow—in coil | 1000 |
| Impeller Pinion | Residual | 1000 |
| Impeller Drive Carrier Support | Residual | 2000 |
| Impeller Shaft | Residual—two ways | 1500 |
| Impeller Shaft Oil Seal Sleeve | Residual | 1500 |
| Governor Drive Gear | Residual—two ways | 1500 |
| Master Rod | See applicable paragraph above | |
| Knuckle Pin | Residual—two ways | 1500 |
| Master Rod End Seal, Disk, & Spacer | Residual | 1000 |
| Master Rod Knuckle Pin Lock Plate | Residual | 1000 |
| Piston Pin | Residual | 1500 |
| Oil Pump Gear | Residual—two ways | 800 |
| Fuel Pump Drive Shaft | Residual | 1000 |
| Reduction Drive Gear Retaining Nut | Residual | 1500 |
| Reduction Drive Gear | Residual—two ways | 2500 |
| Rocker Arm | See applicable paragraph above | |
| Rocker Arm Adjusting Screw | Residual | 500 |
| Rocker Arm Hub Bolt | Residual | 500 |
| Reduction Gear Pinion Carrier | Residual | 2500 |
| Reduction Gear Pinion | Residual—two ways | 2000 |
| Propeller Shaft | See applicable paragraph above | |
| Accessory Drive & Starter Shaft Coupling | Residual | 1500 |
| Push Rod | Residual—end to end | 500-800 |
| Starter Coupling | Residual—two ways | 2000 |
| Supercharger Oil Seal | Residual | 1500 |
| Fuel Pump Drive Shaft Bevel Gear | Residual—two ways | 750 |
| Valve, Intake | See applicable paragraph above | |
| Valve Spring | See applicable paragraph above | |
| Valve Tappet & Roller | Residual | 1000 |

NOTE: All gears and shafts with gears should be magnetized by both the circular method (No. 1 or No. 2 described above) and the longitudinal method (No. 3 described above).

All plain shafts, rings, nuts, and spacers should be magnetized by the circular method (No. 1 or No. 2 described above). See figures 139, 140, 141, 142, 143, 144, and 145 for magnetizing parts.

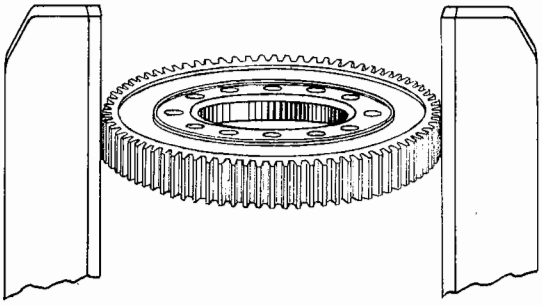


**Fig. 139. Magnetizing Gear**

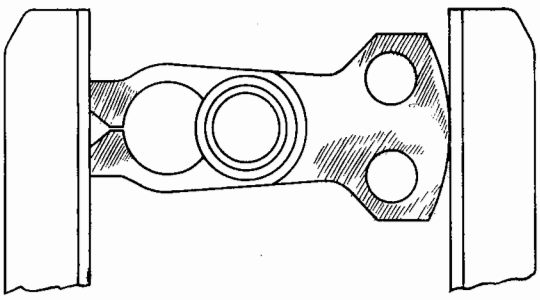


**Fig. 140. Magnetizing Crankcheek**

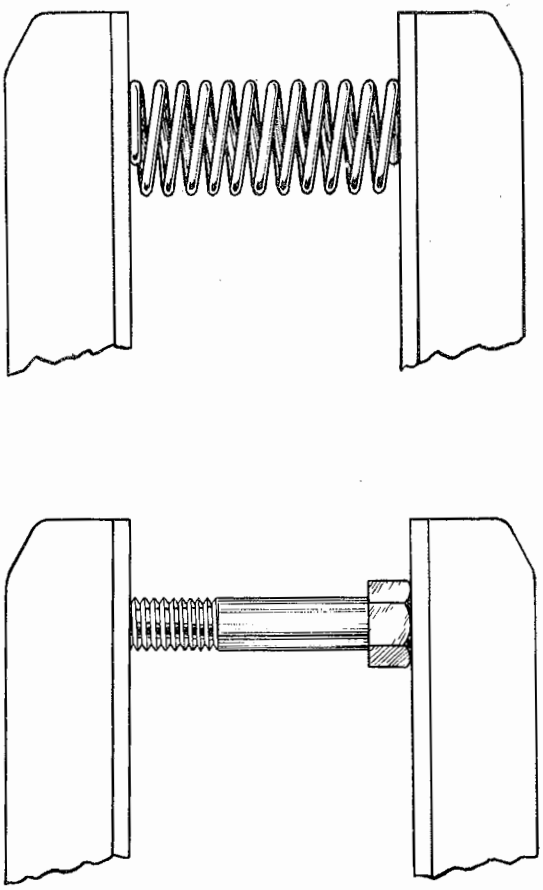


Fig. 141. Magnetizing Small Parts

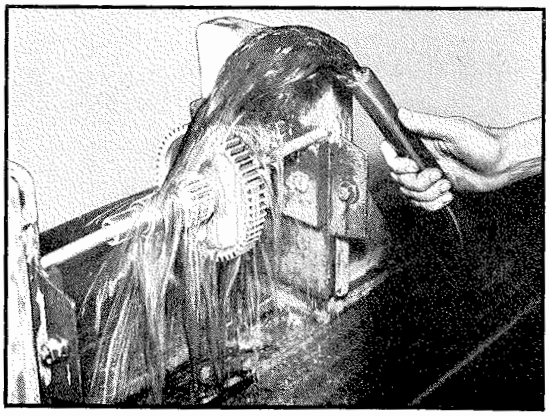


Fig. 142. Magnetizing Impeller Drive and Pinion Gear on Bar

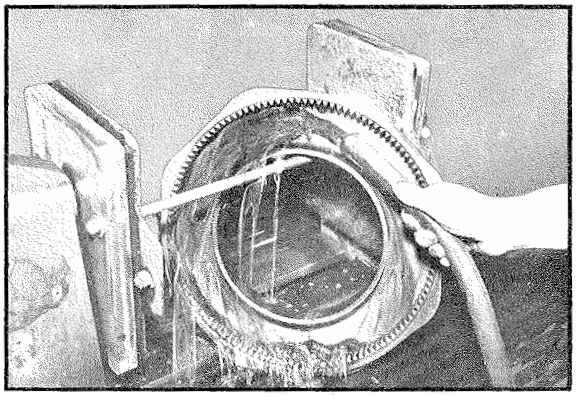


Fig. 143. Magnetizing Cam on Bar

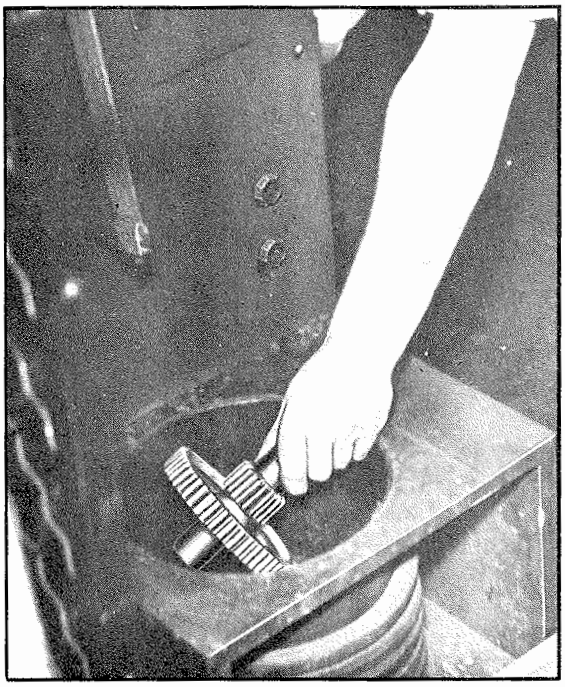


Fig. 144. Magnetizing Impeller Drive and Pinion Gear in Coil

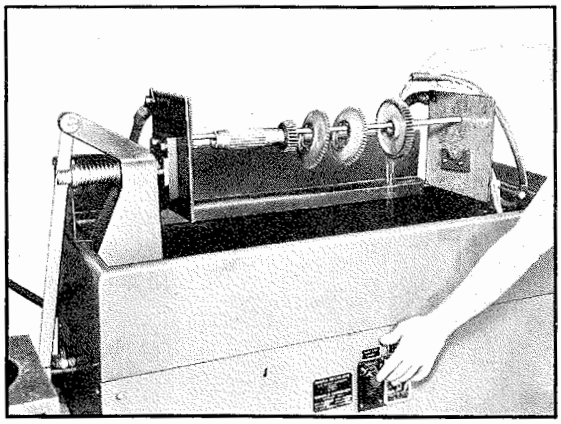


Fig. 145. Magnetizing Tubular and Ring Shaped Parts

# ANTIFRICTION BEARINGS

Do not inspect antifriction bearings by the magnetic-type method. The inspection of an antifriction bearing is best performed after the bearing has been washed, dried, and dipped in light oil.

The condition of antifriction bearings is principally determined by the surface condition of the balls or rollers and races, the axial looseness, and the radial looseness.

The condition of the surfaces can be determined by a visual inspection, using a magnifying glass if necessary. Spinning the bearing while holding it in the hands is not an accurate check of its running qualities, although this test will indicate the presence of dirt or foreign matter in the bearing as evidenced by the bearing sticking in places or turning jerkily. A bearing in this condition should be rewashed, lubricated, and again checked. The sticking of a ball bearing should not be considered as being caused by a flat spot on one of the balls as it is extremely unlikely that such a condition could exist without complete failure of the bearing. A careful check should be made of the surfaces to detect wear or a pitted condition caused by corrosion. Check for overheating, evidenced by discoloration of the balls, races, or retainers. Such a condition must not be confused with discoloration caused by the lubricant. This type of discoloration is merely a thin deposit on the surfaces, is not harmful and therefore need not be removed. **Do not etch** any part of a bearing when inspecting for cracks.

It is not necessary to make a check of the radial looseness of a ball bearing since determination of the axial looseness provides sufficient information to judge the amount of bearing wear. There is a relationship between these two clearances in a ball bearing so that by knowing one the other can be calculated if desired. The most satisfactory method of determining the axial looseness is to clamp the inner race of the bearing securely on a surface plate. Two plugs or flat plates must be used, one under and one over the inner race, the lower one raising the bearing off the surface plate. With a dial indicator located so that its spindle contacts the upper side of the outer race, oscillate the outer race and at the same time press it downward until the maximum reading is obtained.

Reverse the action, this time pulling the outer race upward while oscillating it, and note the difference between the former reading on the indicator and the present one. The difference represents the amount of axial looseness. Refer to the applicable Table of Limits for the maximum permissible axial looseness for each bearing.

The condition of the outer surfaces of the bearing races must be considered when deciding whether or not a bearing is fit for further use. If these surfaces are galled or scored the inspector must decide whether they can be reconditioned by stoning. Ball or roller retainers must be checked for cracks and wear.

Except for stoning the outer surfaces of a bearing to remove scoring or galling, no repairs should ever be attempted on a bearing. Never disassemble a nondemountable-type bearing if it is to be used again.

As soon as a bearing has been inspected, wash it and dip it in clean kerosene, and then pack it with Vaseline.

After cleaning and before packing with Vaseline, the bearing should be thoroughly demagnetized. This applies to all antifriction bearings in the engine, and in the case of demountable-type roller bearings the inner race, spacer, and washer as well as the rollers and outer race should be demagnetized. This operation can be readily accomplished by passing the part through the demagnetizing coil of the magnetic type inspection equipment. CAUTION: Do not attempt magnetic-type inspection on antifriction bearings. Bearings in normal operation tend to pick up a certain amount of magnetism which would hold small metal particles and increase wear. It is for this reason only that all bearings must be demagnetized.

As soon as this is done, wrap the bearing in oiled paper and do not uncover it until the time it is to be assembled in the engine.

# CRANKCASE FRONT SECTION

Inspect the crankcase front section for cracks. Any part of the front section about which the inspector is doubtful as to the presence of a crack should be inspected with a magnifying glass, and if necessary, etched. Extreme care should be exercised in the use of etching fluid. Instructions on etching procedure and the use of proper etching fluid are included in the Appendix entitled SHOP MATERIALS. Use particular care in inspecting the front section in the location of bolt holes and studs, the thrust bearing location, and at the parting flange. **Under no circumstances should a case be used if it is cracked,** and neither should it be welded. Inspect the finished surfaces for scratches or nicks and for high spots around the studs.

Inspect all studs for straightness, tightness, stretching, and condition of the threads. Order replacement of all studs that are bent, loose, stretched, or that show evidence of pulling.

Inspect all oil passages in the front section for cleanliness and freedom from obstruction.

Inspect the flange and the inside diameter of the thrust bearing retainer for galling or roughness, and for tightness in the front section. Inspect the inside diameter of the thrust bearing retainer and the outside diameter of the thrust bearing outer race, using micrometers, to determine the fit. (Refer to the applicable Table of Limits.) If replacement of the thrust bearing retainer is found to be necessary, the crankcase front section must be returned to the factory for this replacement.

Inspect the governor drive gear shaft bushing for scratches, burrs, and wear. Inspect the fit of the governor drive gear shaft in the bushing. (Refer to the applicable Table of Limits.)

Inspect the cap screws which attach the front section to the crankcase front main section for burrs, cracks, straightness, and condition of the threads and hexagonal head.

Inspect the aluminum front section spacer for cracks, smoothness of the contacting surfaces, and condition of the bolt or stud holes. Inspect the steel front section flange for cracks, and the inside diameter of the flange for roughness or wear caused by the thrust nut oil seal ring.

**PROPELLER GOVERNOR DRIVE** Inspect the governor drive gear for cracks and for chipped, cracked, or broken teeth. Inspect the screw holes in the gear for mutilation of the threads. Inspect the governor drive gear shaft for nicks, burrs, and condition of the bearing surfaces. Inspect the screws which attach the gear to the shaft for condition of the threads and the hexagonal head. Inspect the governor substituting cover for cracks and condition of the finished surfaces.

**VALVE TAPPETS** Inspect the outside diameter of all valve tappets for cracks and scores. It is important that these surfaces have a high finish as a precaution against seizure of the tappet in its guide. Check the tappets for the correct dimension on the outside diameter. Tappets with diameters of less than .81125 in. should be replaced. Recheck the tappet diameter in a location 90 deg. from the first checking point to indicate an out of round condition. Order replacement of all tappets which are scored, are not of the correct diameter, or are out of round on the outside diameter. Inspect the tappets for cleanliness of the oil holes and the inside diameter.

Inspect the valve tappet ball sockets for cracks, scores, cleanliness of the oil hole, and wear of the spherical socket. Check the fit of the ball socket in the tappet. (Refer to the applicable Table of Limits.) Check the ball socket springs for proper tension. (Refer to the applicable Table of Limits.) Inspect the tappet rollers for flat spots on the outside diameter, chipped edges, cracks, and pitting. Inspect the roller bushings for cracks and galling, and for fit in the rollers. (Refer to the applicable Table of Limits.) Inspect the roller pins for cracks and galling, and for fit in the roller bushings and tappets. (Refer to the applicable Table of Limits.)

**VALVE TAPPET GUIDES** Inspect all valve tappet guides for cracks and for scoring of the inside diameter. Checks the guides for wear on the inside diameter using plug gage (Tool No. 801071). Accept only tappet guides which permit insertion of the "GO" plug and which do not allow the "NO GO" plug to enter. **Do not use shim stock feeler gages** to measure the diametral clearance between a tappet and guide, since they cause scratches on the polished surface of the tappet and guide. Inspect all tappet guides for cleanliness of the oil holes and for cracks or galling of the attaching flange. Check the fit of the guides in the crankcase front section. (Refer to the applicable Table of Limits.)

**PROPELLER SHAFT** Record the ratio of the propeller reduction gearing. Inspect the propeller shaft for cracks, particularly at the splines and in the location of oil holes. Inspect the threads at the thrust nut and propeller hub nut locations for mutilation. Inspect the propeller shaft splines for burrs, pitting, corrosion, and excessive wear.

Inspect the propeller shaft at the centering cones and thrust bearing locations for scoring, pitting, and galling. Check the outside diameter of the thrust bearing journal on the propeller shaft and the inside diameter of the thrust bearing inner race, using micrometers, to determine the fit. (Refer to the applicable Table of Limits.)

Inspect all oil passages in the propeller shaft for cleanliness and freedom from obstruction, and inspect the radius at the end of the oil holes.

Inspect the front and rear propeller shaft bushings for tightness, cracks, scoring, and wear. Check the inside diameter of the bushings and the outside diameter of the crankshaft journals, using micrometers, to insure that the proper fits are obtained. (Refer to the applicable Table of Limits.)

Inspect the thrust bearing spacer for cracks and condition of the inside and outside surfaces. Inspect the ring grooves for wear and for broken, cracked, or chipped lands. Inspect the lip on the spacer for condition of the seating surfaces and the thrust bearing contacting surface. Check the gap of the spacer rings. See figure 146. Check the inside diameter of the spacer and the outside diameter of the propeller shaft at the spacer location to determine the fit. (Refer to the applicable Table of Limits.)

Check the reduction gear drive pinion bushings in the .666 (3:2) ratio propeller shaft pinion arms for tightness and condition of the inside surfaces. Determine the diametral clearance between the bushings and the pinion journals. (Refer to the applicable Table of Limits.)

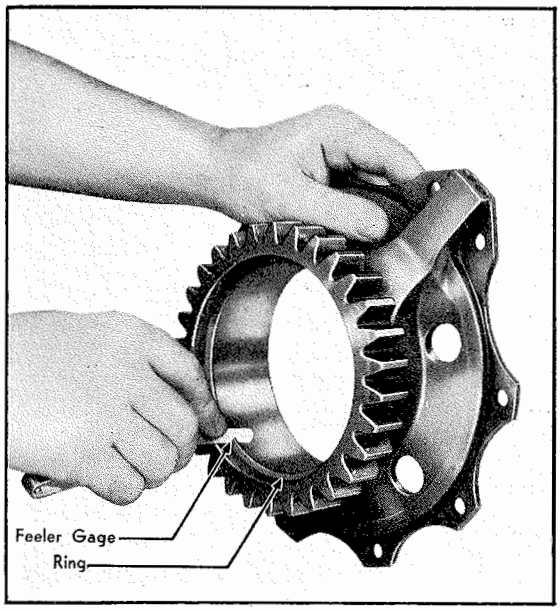



**Fig. 146. Measuring Ring Gap in Thrust Bearing Retaining Flange**

Inspect the thrust nut for cracks, burrs, and mutilated threads. Inspect the ring grooves for wear and for broken, cracked, or chipped lands. Inspect the thrust nut front and rear faces for burring, or galling, and inspect the lugs for mutilation.

**THRUST BEARING** Inspect the thrust bearing balls and races, using a magnifying glass, to determine if there are any cracks and if the surfaces are pitted or galled or have depressions worn in them by the balls. Inspect the retainer for wear and cracks. The presence of any one of these conditions warrants replacement of the thrust bearing. Do not inspect the thrust bearing by the magnetic-type inspection method or by the use of etching

fluid. Determine the axial looseness of the thrust bearing. (Refer to the subtitle ANTI-FRICTION BEARINGS included at the beginning of this chapter.)

**STATIONARY REDUCTION GEAR SUPPORT—.5625 (16:9) RATIO** Inspect the stationary reduction gear support used in .5625 (16:9) reduction geared engines for cracks. Check to make sure that the mounting flange at the front of the support has a good seating contact against its mating surface in the interior of the crankcase front section. It may be necessary to use prussian blue to make an accurate check. A good seating surface on this flange is particularly important in the location of the oil holes in the flange to prevent leakage. Inspect the inside diameter of the support for roughness or wear caused by the spacer oil seal rings. Inspect all oil passages for cleanliness and freedom from obstruction.

**STATIONARY REDUCTION GEAR —.5625 (16:9) RATIO** Inspect the stationary reduction gear used in .5625 (16:9) reduction geared engines for pitted, chipped, cracked, or worn teeth. Inspect the tapped holes in the gear for burred or mutilated threads. Inspect the stationary reduction gear attaching cap screws for general condition, particularly at the threads and hexagonal head.

**STATIONARY REDUCTION GEAR— .666 (3:2) RATIO** Inspect the stationary reduction gear used in .666 (3:2) reduction geared engines for cracks. Check the mounting flange of the stationary reduction gear for good seating contact against the front section in the same manner as the stationary reduction gear support in .5625 (16:9) reduction geared engines is checked. Inspect the inside diameter for roughness or wear caused by the spacer rings. Inspect the oil passages for freedom from obstruction. Inspect the gear teeth for cracks, pitting, chipping, or excessive wear. Inspect the stationary reduction gear attaching bolts and nuts for cracks, burrs at the locking circlet grooves on the bolt, condition of the flats on the nut and bolt heads, and condition of the threads.

**REDUCTION GEAR DRIVE PINIONS** Inspect the reduction gear drive pinions for cracks. Inspect the oil passages for freedom from obstruction. Inspect the gear teeth for galling, pitting, chipping or excessive wear. Inspect the pinion journals for roughness, scoring and galling. Inspect the pinion bushings used in .5625 (16:9) reduction geared engines for galling, scoring, and roughness, and determine the diametral clearance of the bushings on the carrier trunnions and in the pinions. (Refer to the applicable Table of Limits.) Inspect the flanges on these bushings for cracks, galling, and chipping. Inspect the pinion attaching bolts for nicks or burrs on the bearing surfaces and for mutilation of the threads. Inspect the pinion bolt nuts used in .5625 (16:9) reduction geared engines for condition of the threads. Inspect the pinion guard ring for cracks and warping and for galled, pitted, and corroded surfaces.

Inspect the pinion carrier used in .5625 (16:9) reduction geared engines for cracks, particularly at the trunnions and attaching bolt holes. Inspect the condition of the surface which contacts the rear end of the propeller shaft. Inspect the trunnions for nicks, burrs, and wear. Inspect the oil passages for cleanliness and freedom from obstruction. Inspect the bolts and nuts which attach the pinion carrier to the propeller shaft for nicks, burrs, and condition of the threads and heads.

**REDUCTION DRIVING GEAR** Inspect the reduction driving gear for cracks, and inspect the splines and internal and external teeth for pitting, chipping, mutilation, and excessive wear. Inspect the reduction driving gear nut for burred or mutilated threads, and inspect the front face of the nut and hexagonal faces for galling and mutilation. Check the general condition of the reduction driving gear nut lock screw.

**TORQUEMETER PARTS** If the engine is provided with a torquemeter, inspect the torquemeter parts in accordance with the following instructions:

Inspect the torque arm for cracks, particularly at the splines. Inspect the recess in the end of the torque arm, which accommodates the torquemeter valve, for cracks, galling, scratching, and excessive wear. Inspect the ball races of the torque arm and support for pitting and for depressions worn by the balls. Make a visual inspection of the balls for flats.

Replacement of detail parts in the torque arm and support assembly is impossible because these parts are matched with precision. Consequently, if inspection of these parts reveals any of the defects described in the previous paragraph, the entire torque arm and support assembly must be replaced or returned to the factory for repair.

Inspect the torquemeter valve for cracks. Inspect the button at the end of the valve stem, and the stem itself, for galling, scratching or pitting caused by contact with the torque arm. Inspect the ring groove around the head of the valve for wear.

Inspect the torquemeter housing and cover for cracks. Check the valve housing for tightness in the torquemeter housing, and inspect the valve housing sleeve for scratching or scuffing caused by the valve ring and for tightness in the housing. Inspect the oil passages in the housing for cleanliness. Check the general condition of the torque arm stop screw and lock nut. Inspect the tapped holes in the top of the torquemeter housing for condition of the threads, and check the thread condition of the nuts which attach the housing to the front section. Inspect also the bolts and nuts which attach the torquemeter housing cover to the housing.

Inspect the torquemeter booster pump housing and cover for cracks. Inspect the booster pump gear recesses in the housing, and the bores in the housing and cover which accommodate the booster pump gear shafts, for burrs, scoring, chafing, and wear. Inspect the oil passages in the housing and cover for cleanliness and freedom from obstruction. Inspect the thread condition of the cap screws which attach the booster pump housing to the torquemeter housing and the nuts which attach the booster pump housing to the front section. Inspect the booster pump gears for cracks and for pitted, galled, or excessively worn teeth.

## CRANKCASE FRONT MAIN SECTION

Inspect the crankcase front main section for cracks, galling, and chafing, particularly at the parting surfaces and at the cylinder mounting pads. Check the condition of the threads in the main section front flange in which the crankcase front section attaching cap screws are installed. Check the condition of the threads in the cylinder hold-down cap screw holes in the cylinder mounting pads. Inspect the two hollow dowels in the lower part of the main section front flange, which constitute part of the oil scavenge passages, for tightness in the main section and for freedom from obstruction.

Inspect the internal main section attaching lugs for bending, chafing marks, and cracks. Inspect the main section attaching nuts and bolts for cracks, straightness, burrs, and condition of the threads and hexagonal heads.

Inspect the cam bearing ring for burrs, scoring, galling, and wear of bearing surface and flanges. Inspect the splines in the front flange for wear and mutilation. Inspect the oil passages and grooves for cleanliness. Check the diametral clearance between the cam and the cam bearing ring. (Refer to the applicable Table of Limits.)

Inspect the front main bearing ring for scoring, galling, excessive wear, and tightness in the main section. (Refer to the applicable Table of Limits.) Inspect the bearing ring flange for cracks, and inspect the threads in the tapped holes in the flange for mutilation. Inspect the inside diameter of the flange for roughness and wear caused by the reduction driving gear spacer oil seal rings. Measure the inside diameter of the bearing ring and the outside diameter of the crankshaft front main bearing outer race, using micrometers, to insure that the proper fit is obtained. (Refer to the applicable Table of Limits.)

Inspect the reduction driving gear spacer for cracks. Inspect the ring grooves for wear and mutilation, and inspect the oil passages for cleanliness.

**CAM AND CAM DRIVE** Inspect the cam for cracks. Inspect the cam lobes for pitting, galling, and scoring, and for wear or flat spots in the tappet roller tracks. Inspect the internal gear teeth on the cam for pitting, chipping, or excessive wear. Inspect the cam hub bore for scores, scratches, and burrs.

Inspect the cam drive gear bracket for cracks, nicks, and burrs. Check the cam drive gear bushing for tightness in the bracket and for scratches, burrs, and wear. Inspect the screws which attach the cam drive gear bracket, bracket spacer, and cam bearing ring spacer to the main section for wear and condition of the threads and head. Inspect the cam drive gear bracket spacer for scoring, galling, or mutilation of the contacting surfaces, and inspect the cam bearing ring spacer for the same conditions and for wear and mutilation of the splines.

Inspect the cam drive gear and the intermediate governor drive gear for cracks and for pitted, chipped or broken teeth. Inspect the cam drive gear shaft for nicks, burrs, and condition of the bearing surfaces, and inspect the splines at the end of the shaft for mutilation and excessive wear. Check the fit of the cam drive gear shaft in the bushing. (Refer to the applicable Table of Limits.) Inspect the screws which attach the intermediate governor drive gear to the cam drive gear for condition of the threads. Inspect the cam drive gear spacer for wear and mutilation of the contacting surfaces and flange. Inspect the cam drive gear pinion for cracks and for pitted, chipped, and broken teeth and splines. Inspect the cam drive gear and pinion bolt and nut for burrs, cracks, straightness, and for mutilated threads, and inspect the slot in the head of the bolt for mutilation.

## CRANKCASE REAR MAIN SECTION AND SUPERCHARGER FRONT HOUSING

**CRANKCASE REAR MAIN SECTION** Inspect the crankcase rear main section for cracks, galling, and chafing, particularly at the parting surfaces and at the cylinder mounting pads. Check the condition of the threads in the main section rear flange in which the supercharger front housing attaching cap screws are installed. Check the condition of the threads in the cylinder hold-down cap screw holes in the cylinder mounting pads. Inspect the four hollow dowels in the lower parts of the main section rear flange, which constitute part of the oil scavenge passages, for tightness in the main section and for freedom from obstruction. Inspect the internal main section attaching lugs for bending, chafing marks, and cracks.

Inspect the rear main bearing ring for scoring, galling, excessive wear, and tightness in the main section. Measure the inside diameter of the bearing ring and the outside diameter of the crankshaft rear main bearing outer race, using micrometers to insure that the proper fit is obtained. (Refer to the applicable Table of Limits.) If replacement of the rear main bearing ring is found to be necessary, the rear main section must be returned to the factory for this replacement.

**SUPERCHARGER FRONT HOUSING** Inspect the supercharger front housing for cracks, nicks, and chafing, particularly at the parting surfaces. Inspect the rear side of the web of the supercharger front housing for roughness, excessive wear, and depression caused by chafing of the diffuser plate vanes.

Inspect the finished surfaces for high spots around the studs. Inspect all studs for straightness, tightness, stretching, and condition of the threads. Order replacement of all studs that are bent, loose, stretched, or that show evidence of pulling.

Inspect all oil scavenge and breather passages in the supercharger front housing for cleanliness.

Inspect the cap screws which attach the supercharger front housing to the crankcase rear main section for burrs, cracks, straightness, and condition of the threads and hexagonal head.

Inspect the engine mounting lugs for cracks and excessive wear.

Inspect the intake port threads for stripping, burrs, and other mutilation. Inspect the intake pipe packing nuts for cracks and for stripped, burred, or mutilated threads. Inspect the lugs on the end of the nuts for bending and other mutilation.

Inspect the impeller shaft bearing support and ring for cracks, smoothness of the contacting surfaces, and condition of the cap screw holes. Inspect the inside diameter of the support for roughness or wear caused by the impeller shaft front oil seal rings.

**SUPERCHARGER FRONT HOUSING BREATHER** Inspect the breather or substituting cover for cracks and condition of the finished surfaces. Inspect the breather screen for clogging and mutilation. Check the operation of the breather relief valve by forcing the valve open. Visually inspect the condition of the valve seat.

## SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER

**SUPERCHARGER REAR HOUSING** Inspect the supercharger rear housing for cracks, galling, and chafing, particularly at the parting surfaces and in the location of bolt holes and studs. Inspect the finished surfaces for scratches and nicks and for high spots around the studs. Inspect all studs for straightness, tightness, stretching, and condition of the threads. Order replacement of all studs which are bent, loose, stretched, or that show evidence of pulling. Inspect all oil passages in the supercharger rear housing for cleanliness and freedom from obstruction.

Inspect the copper fuel venturi extension tube, which is spun into the lower part of the rear housing, for cracks, tightness in the housing, and for condition of the attaching bracket. Inspect the manifold pressure gage tube, which crosses the induction passage in the supercharger rear housing horizontally, for cracks and for tightness in the housing. Inspect the oil seal vent tube, which crosses the induction passage vertically, for cracks and for tightness in the housing. Inspect the umbrella-type oil seal vent for cracks, mutilation of the threads, and obstruction of the vent passages.

Inspect the rear impeller shaft sleeve for tightness in the rear housing and for roughness and wear on the inside diameter caused by the impeller shaft rear oil seal rings. Inspect the flange at the rear end of this sleeve for scoring, galling, and excessive wear caused by contact with the impeller shaft gear washer.

Inspect the impeller drive gear front bushing for tightness in the rear housing, and for scratches, burrs, and wear. Check the fit of the impeller drive gear front journal in the bushing. (Refer to the applicable Table of Limits.)

Inspect the nuts which attach the supercharger rear housing to the supercharger front housing for mutilation of the threads and hexagonal faces.

**DIFFUSER PLATE** Inspect the diffuser plate for cracks. Inspect the vanes for nicks, burrs, and other mutilation on the edges which contact the supercharger front housing. Inspect the inside diameter of the diffuser plate for scratches and roughness. Inspect the nuts which attach the diffuser plate to the supercharger rear housing for proper cotterpinning.

**GUN SYNCHRONIZERS, DRIVE SHAFTS, AND SUPPORTS** Inspect the lower and upper plunger housings of each gun-synchronizer impulse generator for cracks and for mutilation of the mounting surfaces. Inspect the

threads in the plug holes in the lower and upper housings and on the plugs for mutilation. Inspect the studs in each lower housing for straightness, tightness in the housing, and condition of the threads. Inspect each laminated shim for bending, uniform thickness, and mutilation. Check the thread condition of the housing attaching nuts and cap screws.

Inspect each plunger for cracks, galling, picking-up, and excessive wear. Check the fit of the plunger in the upper housing, and check the side clearance between the plunger and the interior of the lower housing. (Refer to the applicable Table of Limits.) Inspect the internal threads in one end of the plunger for mutilation and inspect the other end for condition of the spline. Inspect each valve tappet roller for a free, true, running condition, and for scoring, pitting, and excessive wear on the outside diameter of the roller. Check the side clearance between the rollers and plungers. (Refer to the applicable Table of Limits.)

Inspect each cam for cracks, and for scoring, pitting, and excessive wear of the lobe. Inspect the tapered bore of the cam for a galled, burred, or picked-up condition. It is important that this bore be smooth to insure proper seating of the cam on the drive shaft upon tightening of the retaining nut. Inspect the threads in the nut for mutilation.

Inspect each gun-synchronizer impulse generator drive shaft and support for cracks. Inspect the spiral teeth on the shaft for pitting, chipping, and wear. Inspect the drive shaft journals for scratches, burrs, and wear. Inspect the tapered portion of the shaft, upon which the cam is installed, for galling and burring. Inspect the drive shaft thrust plug for galling and burring, and for tightness in the shaft. Inspect the threads on the end of the shaft for mutilation.

Inspect the flange on each gun-synchronizer drive shaft support for scoring, nicks, and scratches. Check the bushings pressed into the support for tightness in the support, and for scratches, burrs, and wear. Check the fit of the shaft in the support bushings. (Refer to the applicable Table of Limits.)

If the engine is not equipped with gun-synchronizer impulse generators, inspect the gun-synchronizer substituting covers which were removed from the gun-synchronizer mounting pads on the supercharger rear housing for cracks and for condition of the finished surfaces. If extended-type substituting covers are used, inspect the plug extension for cracks, and for excessive mutilation and wear which might cause oil leakage.

**FUEL PUMP DRIVE SHAFT AND SUPPORT** Inspect the fuel pump drive shaft and the fuel pump drive shaft support for cracks. Inspect the spiral teeth on the shaft for pitting, chipping, and wear. Check the fit of the shaft in the support bushings. (Refer to the applicable Table of Limits.) Inspect the drive shaft thrust plug for burring and galling and for tightness in the shaft. Inspect the splines on the inside diameter of the shaft for pitting, chipping, and mutilation.

Inspect the flange on the fuel pump drive shaft support for scoring, nicks, and scratches. Inspect the bushings pressed into the support for scratches, burrs, and wear, and for tightness in the support. Check the condition of the leather oil seal in the flanged end of the support, and check the tightness of the seal in the support. Inspect the fuel pump substituting cover for cracks, and check the condition of the finished surface.

**CUNO OIL FILTER** Inspect the cartridge of the Cuno oil filter for bent or damaged cleaner disks and blades. Check the condition of the threads in the attaching nuts.

Inspect the Cuno oil filter in the test fixture to insure that the automatic turning mechanism is functioning properly. Use for this purpose the same fixture which is used for cleaning the Cuno filter. (Refer to the section in the Appendix entitled SHOP MATERIALS.) To check the automatic motor head, plug the flushing oil inlet and outlet connections in the fixture, open the air outlet connection, and introduce an air pressure of 40 to 50 pounds per square inch (2.8 to 3.5 kg./sq.cm.) into the air inlet connection. See figure 147. This causes the automatic turning mechanism to operate, which will be indicated by rotation of the indicator flag on the fixture and also

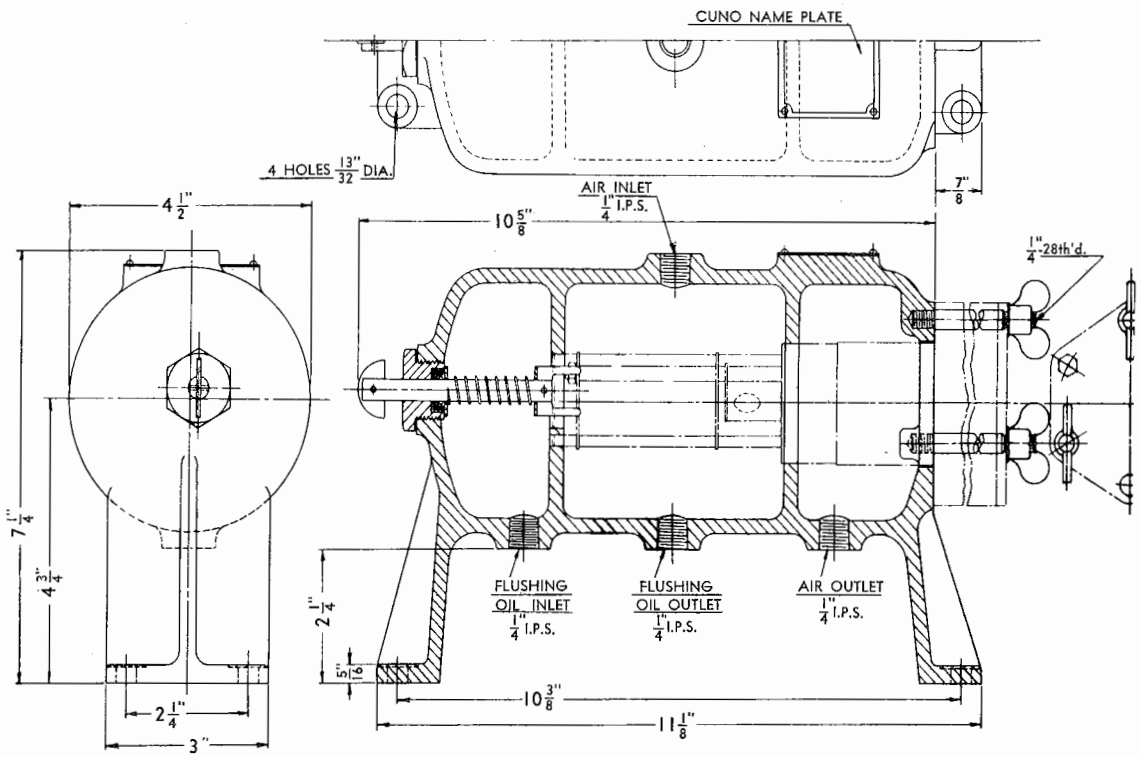



**Fig. 147. Cuno Test Fixture**

by clicking of the valve mechanism in the filter head, which should be readily heard. If the flag does not turn and the clicking of the valve mechanism cannot be heard, the filter should be returned to the Cuno Engineering Corporation, Meridan, Connecticut, for repair, and a filter which operates satisfactorily should be used in the engine. If the valve mechanism can be heard clicking, but the indicator flag remains stationary although in proper engagement with the cartridge, that is usually an indication that the clutch is inoperative and requires repair. Do not operate the filter by air pressure any longer than is necessary to check the operation of the automatic turning mechanism.

Check the relief valve for satisfactory operation by using a rod to actuate the valve to determine if it is seating properly, if its operation is sluggish, or if it is sticking in an open or partially open position. This check is most important, since it is possible that a small amount of dirt may accumulate in back of the valve or on the valve, thereby making the valve operation sluggish or holding the valve in a partially open position. On Cuno filters which do not have a sludge tube at the relief valve opening, this check may be made using the eraser end of a common pencil. See figure 148. On filters which are equipped with

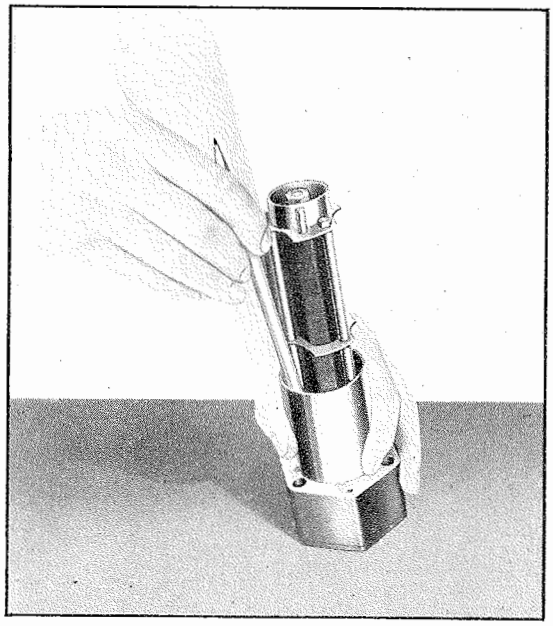


**Fig. 148. Checking Cuno Relief Valve Operation**

the sludge tube, a small rod may be inserted through the ⅛ inch diameter hole in the end of the sludge tube to perform this check. If sticking or improper seating of the relief valve is observed which cannot be corrected by cleaning of the valve assembly, it is recommended that the filter unit be returned to the Cuno Engineering Corporation, for repair.

**SUPERCHARGER DRAIN VALVE ASSEMBLY** Inspect the supercharger drain valve plug for mutilation and condition of the threads. Inspect the drain valve housing for condition of the finished surfaces and cracks, and check the condition of the threads. Inspect the disk for bending and mutilation and determine if the disk seats properly on the valve housing. Inspect the valve body for condition of the threads at each end of the body, for cracks, and for condition of the seat. Check the thread condition of the internal and external threads on the drain valve bushing. Inspect the venturi tube for cracks, bending, and tightness of the brazed tip in the tube. Inspect the orifice in the tip to insure that it is clear.

**SUPERCHARGER REAR HOUSING COVER** Inspect the supercharger rear housing cover for cracks, galling, and chafing, particularly at the finished surfaces and in the location of bolt holes and studs. Inspect the finished surfaces for scratches and nicks and for high spots around tapped holes and studs. Inspect all studs for straightness, tightness, stretching, and condition of the threads. Inspect all oil passages in the rear cover for cleanliness.

Inspect the oil pressure gage tube for cracks and for tightness in the rear cover.

Inspect the accessory drive and starter shaft bushing, magneto drive gear shaft bushings, oil pump drive gear shaft bushing, dual accessory drive gear shaft bushing, and generator drive gear bushing for tightness in the rear cover, scratches, burrs, and wear. Check the fit of the respective shafts in these bushings. (Refer to the applicable Table of Limits.) Inspect to insure that one of the three slots in the accessory drive and starter shaft bushing is located directly opposite the oil passage leading from the Cuno oil filter recess. If a slot in the bushing is not lined up with the Cuno oil passage, order replacement of the bushing, since this condition may restrict the oil flow.

Inspect the gun synchronizer drive shaft thrust bushings, if used, and the fuel pump drive shaft thrust bushing for burring and galling and for tightness in the rear cover.

Inspect the intermediate impeller drive shaft rear bushing for tightness in the rear cover and for proper staking of the attaching screws. Inspect the inside diameter of the bushing for scratches, burrs, and wear. Check the fit of the impeller drive gear rear journal in the bushing. (Refer to the applicable Table of Limits.)

Inspect the starter and generator substituting covers for cracks and condition of the finished surfaces.

Inspect the oil vent connection for cracks and condition of the finished surfaces and internal threads.

**ACCESSORY DRIVE AND STARTER SHAFT** Inspect the accessory drive and starter shaft for cracks, particularly in the location of splines and oil holes. Inspect the journals for scratches, burrs, and wear. Inspect the oil seal ring grooves for burred, chipped, or worn edges. Inspect the splines on the antigear end of the shaft for pitting, chipping, and excessive wear. Inspect the internal splines in the large end of the shaft for chipping, corrosion, burring, and wear. Inspect the inside diameter of the shaft and all oil passages for cleanliness.

Support the accessory drive and starter shaft on two identical V-blocks located under the impeller shaft front and rear bushing journals in such a way that the two oil flats are on top. This check should be performed on a surface plate. Inspect the shaft for twist, using a dial indicator, in the following manner: Turn the shaft until the rear flat is exactly level. Install the indicator in a surface gage and set the indicator to zero with the indicator finger contacting the rear flat. Move the indicator to the front flat and note the gage reading. The maximum permissible tolerance in height of these flats at manufacture is .010 inch (.254 mm), and a greater difference

than this in the height of the flats is an indication that the shaft is twisted. Reject a shaft that is found to be twisted.

Inspect the accessory drive and starter shaft springs for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the spring retaining pins for cracks and scoring. Inspect the accessory drive gear rear plate for cracks, scratches, and scoring. Inspect the screws which attach the plate to the shaft for condition of the threads and screwdriver slot. Inspect the gear for cracks and for pitted, chipped, cracked, and excessively worn teeth.

Inspect the bronze accessory drive and starter shaft thrust ring for cracks, burring, scoring, and galling. Inspect the accessory drive and starter shaft spacer for cracks, and burring, scoring, galling, and roughness on the ends. Inspect the starter dog for cracks, inspect the splines for pitting, chipping, burring, and wear, and inspect the jaws for burred and broken edges and for scoring and galling. Inspect the sintered starter shaft oil seal packing for cracks, scratches, galling, picking-up, and wear. Inspect the starter shaft oil seal packing retainer for cracks and condition of the finished surfaces.

**GENERATOR DRIVE GEAR AND OIL SEAL** Inspect the generator drive gear for cracks, for pitted, chipped, burred, and worn teeth and splines, and for burring, scoring, and roughness of the journal. Inspect the generator drive gear cup plug for tightness in the shaft.

Inspect the generator drive oil seal retainer for cracks, scratches, and condition of the finished surfaces. Inspect the collars for cracks, scratches, scoring, and condition of the finished surfaces and splines. Check the fit of the end of the shaft in the collar. (Refer to the applicable Table of Limits.) Inspect the sintered retaining ring and flanged washer for cracks, scoring, and mutilation, and for condition of the lugs. Check the springs for cracks and for proper tension. (Refer to the applicable Table of Limits.)

**MAGNETO DRIVE GEARS, SHAFTS, AND OIL SEALS** Inspect the magneto drive gears and shafts for cracks. Inspect the teeth on the gears for pitting, chipping, burring, and wear. Inspect the gear attaching screws and the tapped holes in the shafts for condition of the threads. Inspect the shafts for burrs, scores, picking-up, and roughness on the journals. Inspect the spiral gear teeth on the shafts for pitting, chipping, burring, and wear. Inspect the internal splines in the end of the shafts for pitting, chipping, mutilation, and wear. Inspect the magneto drive gear shaft plug for tightness in the shaft.

Inspect the parts of each magneto drive oil seal assembly in the same manner as the corresponding parts in the generator drive oil seal assembly are inspected.

**OIL PUMP DRIVE GEAR** Inspect the oil pump drive gear in the same manner as the generator drive gear is inspected.

**DUAL ACCESSORY DRIVE GEAR AND SHAFT** Inspect the dual accessory drive gear and shaft in the same manner as the magneto drive gears and shafts are inspected.

**IMPELLER** Inspect the impeller for cracks in the hub and blades. Inspect the blades for scratches, burrs, roughness, and evidence of rubbing against the diffuser plate. Inspect the splines for burrs, pitting, galling, picking-up, and wear. Check the fit of the impeller on the impeller shaft by hand. (Refer to the applicable Table of Limits.) An impeller which slides easily on the impeller shaft all the way should not be used since excessive spline wear may result from such a condition. A proper fit is obtained with an impeller which may be installed approximately half way by hand.

**IMPELLER SHAFT** Inspect the impeller shaft and integral gear for cracks, particularly in the location of the threads, splines, and gear teeth. Inspect the threads on the antigear end of the shaft for mutilation and general condition. Inspect the splines and gear teeth for pitting, burring, chipping, galling, and wear. Inspect the impeller shaft front and rear bushings for burrs, scratches, galling, wear, and tightness in the shaft. Check the fit of the accessory drive and starter

shaft in the bushings. (Refer to the applicable Table of Limits.)

Inspect the front and rear impeller shaft oil sleeves for cracks, burring, and galling. Inspect the ring grooves for wear and for chipped, burred, and broken lands. Check the fit of the front and rear sleeves on the impeller shaft. (Refer to the applicable Table of Limits.) Inspect the impeller shaft gear bronze washer for cracks, scratches, burring, and scoring. Inspect the impeller shaft thrust ring steel washer for cracks, scratches, and burring, and for condition of the splines. Inspect the spherical thrust ring for cracks, nicks, burrs, and scores. Inspect the impeller shaft retainer for cracks, condition of the finished surfaces, and chipping, burring and wear of the ring groove. Inspect the shim for bending and mutilation. Inspect the impeller shaft front nut for cracks, nicks, and burrs, and for mutilation of the threads and slots.

**IMPELLER DRIVE GEAR AND PINION (SINGLE-SPEED)** Inspect the impeller drive gear and pinion and integral shaft for cracks, for pitted, burred, chipped, and worn teeth, and for burred, scratched, scored, and worn journals.

**IMPELLER DRIVE (TWO-SPEED PLATE-CLUTCH TYPE)** Inspect the low-speed impeller drive multiplate clutch sleeve for cracks, for roughness and wear on the inside diameter caused by the piston ring, for chipping, burring, and wear of the splines, and for good seating contact of the flange on its mounting pad in the rear cover.

Inspect the low-speed clutch piston for cracks, nicks, and scuffing, for chipping, burring, and wear of the splines, and for chipped, burred, and broken edges of the ring groove. Inspect the piston lock for tightness in the piston and for bending and mutilation of the lugs. Check the fit of the piston on the intermediate impeller drive shaft rear bushing. (Refer to the applicable Table of Limits.)

Check the low-speed clutch release spring for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the low-speed clutch thrust spacer for cracks, and for burring, scoring, and scuffing of the contacting surfaces. Inspect the low-speed clutch thrust washer for cracks, for burring, scoring, and scuffing of the contacting surfaces, and for bending and mutilation of the lugs.

Inspect the low-speed clutch disks and plates for cracks, scuffing, scoring, wear, and indications of overheating. Inspect the lugs on the plates and the internal splines on the disks for nicks and wear. Inspect the bronze facing on the disks for cracking, flaking, or breaking away from the steel. Order replacement of the disks on which the bronze is cracked, flaked, or does not adhere to the steel.

Inspect the low-speed clutch housing for cracks, for nicks and wear of the slots, and for good seating contact of the mounting flange on the flange of the low-speed clutch sleeve.

Inspect the sun gear for cracks, for nicking, scoring, and scuffing of the contacting surfaces and inside diameter, and for burring, pitting, galling, and wear of the teeth and splines. Check the fit of the sun gear inside diameter on the intermediate impeller drive shaft bushing. (Refer to the applicable Table of Limits.) Inspect the intermediate impeller drive shaft bushing for burrs, scratches, galling, and wear, and for cleanliness of the oil holes. Check the fit of the intermediate impeller drive shaft in the bushing. (Refer to the applicable Table of Limits.)

Inspect the intermediate impeller drive shaft for cracks, and for pitting, burring, chipping, and wear of the splines. Inspect the shaft also for roughness, scoring, and galling of the bearing journals, for nicks, burrs, and wear of the trunnions, and for cleanliness of the inside diameter and oil passages. Insure that the oil distributor plug is tight in the shaft and that the retaining pin is secure. Inspect the oil check valve for cracks and condition of the seat and check the oil check valve spring for cracks and proper tension. (Refer to the applicable Table of Limits.) Inspect the threads on the check valve plug and in the end of the oil distributor plug for mutilation.

Inspect the pinion for cracks, for pitted, chipped, and worn teeth, for roughness and wear of the inside diameter, and for cleanli-

ness of the oil holes. Inspect the pinion bushings for cracks, burrs, and scoring, and for cleanliness of the oil holes. Check the fit of the bushings on the trunnions and in the pinions. (Refer to the applicable Table of Limits.) Inspect the pinion gear horseshoe locks for wear and general condition.

Inspect the intermediate impeller drive gear for cracks. Inspect the splines and internal teeth on the gear for pitting, chipping, mutilation, and excessive wear. Inspect the intermediate impeller drive gear bushing for burrs, scratches, scoring, and tightness in the gear. Check the fit of the intermediate impeller drive shaft in the bushing. (Refer to the applicable Table of Limits.)

Check the high-speed clutch release spring for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the high-speed clutch disk retainer, disks, and plates for cracks, scuffing, scoring, wear, and indications of overheating. Inspect the internal splines on the disks and the external splines on the plates and retainer for nicks and wear. Inspect the lock wire groove in the outside diameter of the retainer for burrs and wear. Inspect the bronze facing on the disks for cracking, flaking, or breaking away from the steel. Order replacement of disks on which the bronze is cracked, flaked, or does not adhere to the steel.

Inspect the high-speed clutch adapter for cracks, nicks, burrs, and scores, and for burring, pitting, galling and wear of the internal and external splines. Inspect the high-speed clutch piston for cracks, nicks, and scuffing, and for chipped, burred, and broken edges of the ring groove. Check the fit of the piston on the intermediate impeller drive shaft. (Refer to the applicable Table of Limits.) Inspect the impeller drive gear for cracks, for pitted, burred, chipped, and worn teeth and splines, and for a burred, scratched, scored, and worn journal. Inspect the lock wire groove in the gear for burrs and wear, and the slots in the web of the gear for mutilation and wear.

**IMPELLER DRIVE (TWO-SPEED ROLLER-CLUTCH TYPE)** Inspect all gears for condition of the teeth, cracks, and abnormal wear. Examine the impeller drive gear for condition of the internal and external teeth, wear of the bearing journal, condition of the internal bushing, and cleanliness of the oil passages.

Inspect the front and rear halves of the pinion cage for cracks, nicks, burrs, wear, cleanliness of the oil passages, condition of the splines, and for the condition of the bushing holes. Since the pinion bushings are the floating type, the bore should be free from roughness. Check the condition of the pinion journals for wear and smoothness.

Inspect the intermediate impeller drive shaft for cracks, nicks, burrs, wear, condition of the bearing journals, and cleanliness of the oil passages. Inspect the intermediate impeller drive gear for condition of the splines and tightness of the bushing. Check the bushing for scores and wear.

Examine the roller retainer for cracks, wear, scuffing, and galling. Inspect the intermediate impeller drive shaft thrust washer for scores and scuffing. Examine the cam surface for galling, scuffing, and wear. Check the cam splines for burrs, galling, and wear. Check the roller cage for wear, nicks, and burrs. Examine the rollers for flat spots, scuffing, nicks, and wear.

Inspect the high-speed clutch housing for cracks, wear, and for the condition of the clutch plate lug slots. Check the clutch adapter for cracks, burrs, and condition of the splines. Examine the high-speed clutch thrust washer and spacer for cracks, nicks, and wear. Inspect the clutch plates and disks for scuffing, cracks, wear, and dishing or warping. Check the clutch release spring for proper tension. Refer to the Tables of Limits.

Inspect the piston for scuffing, cracks, nicks, and for the condition of the splines and piston ring groove.

Inspect the high-speed clutch sleeve for evidence of ring wear, nicks, and condition of the splines.

**TWO-SPEED CLUTCH CONTROL** Inspect the two-speed supercharger clutch control housing or substituting cover for cracks. Inspect the inside diameter of the housing for nicks, scores, and wear. Inspect the valve for cracks, condition of the threads, cleanliness of the oil passages, and scratching, burring, and scuffing of the

outside diameter. Inspect the spring for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the control valve sleeve for cracks, cleanliness of the oil passages and grooves, and scratching, burring, and scuffing of the outside and inside surfaces. Check the fit of the valve in the sleeve and the sleeve in the rear cover. (Refer to the applicable Table of Limits.)

**OIL PUMP BODY, GEARS, END PLATE, AND COVER** Inspect the oil pump body for cracks and condition of the finished surfaces. Inspect the studs for straightness, tightness, stretching, and condition of the threads. Inspect the diameter and the bottom of the gear recesses for nicks, scores, and wear. Inspect all oil passages in the oil pump body for cleanliness and freedom from obstruction. Inspect the drilled holes in the body which accommodate the oil pump drive shaft, the suction pump idler gear shaft, and the pressure pump idler gear shaft, for burrs, scoring, roughness, and wear.

Inspect the oil pump drive shaft for cracks. Inspect the threads on the shaft for mutilation and general condition. Inspect the splines and gear teeth for pitting, burring, chipping, galling, and wear. Inspect the oil pump drive shaft journals for burrs, scratches, galling, and wear. Check the fit of the journals in the oil pump body and in the oil pump body front end plate. (Refer to the applicable Table of Limits.) Inspect the oil pump drive coupling gear for cracks, and for pitting, burring, chipping, galling, and wear of the gear teeth and internal splines. Inspect the coupling gear nut for mutilation and burring of the threads, hexagonal faces, and cotterpin slots.

Inspect the oil suction pump idler gear shaft for cracks, burring, scratching, galling, and wear. Check the fit of the shaft in the oil pump body and end plate, and check the fit of the suction pump idler gear on the shaft. (Refer to the applicable Table of Limits.) Inspect the oil suction pump idler gear teeth and inside diameter for cracks, pitting, burring, chipping, and wear.

Inspect the oil pressure pump drive gear and idler gear for pitted, chipped, cracked, and worn teeth, and for burred, scratched, galled, and worn journals. Inspect the internal splines in the pressure pump drive gear for pitting, burring, chipping, and wear. Check the fit of the drive gear shaft in the oil pump rear cover. (Refer to the applicable Table of Limits.) Check the fit of the idler gear shaft in the oil pump body and in the cover. (Refer to the applicable Table of Limits.)

Check the end clearance between all oil pump suction and pressure gears and the oil pump body front end plate and rear cover. (Refer to the applicable Table of Limits.)

Inspect the oil pump body front end plate for cracks, and for scratching, nicking, scoring, and warping of the finished surfaces. Inspect the oil pump rear cover for cracks, for burrs, scoring, and roughness of the drilled holes which accommodate the oil pressure pump drive gear shaft and idler gear shaft, and for straightness, tightness, and thread condition of the studs.

Inspect the oil pump inlet and outlet flanges for burring and mutilation of the finished surfaces and threads. Inspect the thread condition of the plugs and the holes in the oil pump body.

Inspect the oil check valve body, which remains installed in the oil pump body, for pitting, burring, and scoring on the inside diameter.

**OIL PUMP CHECK VALVE** Inspect the oil pump check valve, if used, for cracks, pitting, burring, and scoring, and for chipped, burred, and broken edges of the ring groove. Check the fit of the valve in the body. (Refer to the applicable Table of Limits.) Check the valve spring for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the check valve retainer for condition of the threads and hexagonal head.

**OIL PRESSURE RELIEF VALVE** Inspect the oil pressure relief valve body for cracks, for pitting, burring, and scoring on the inside diameter, and for mutilation of the threads and slots. Inspect the valve for cracks, pitting, and scuffing. Check

the fit of the valve in the body. (Refer to the applicable Table of Limits.) Check the relief valve spring for cracks and for proper tension. (Refer to the applicable Table of Limits.) Inspect the lock nut, adjusting nut, and cap for mutilation of the threads, and inspect the flanged washers for mutilation.

**TACHOMETER DRIVE GEAR HOUSING, GEARS, AND COVER** Inspect the tachometer drive gear housing for cracks, and for scratching, nicking, scoring, and warping of the finished surfaces. Inspect the electric tachometer drive shaft front bushing for scratches, burrs, tightness in the housing, and wear. Check the fit of the electric tachometer drive shaft in the bushing. (Refer to the applicable Table of Limits.)

Inspect the tachometer drive gear shaft and the mechanical and electric tachometer drive shafts for pitted, chipped, cracked, and worn gear teeth, and for burred, scratched, galled, and worn journals. Inspect the spring-loaded plug in the end of each of these shafts to insure that they move freely, and that the retaining pins are secure. Inspect the oil seal rings and retainers for mutilation. Inspect the splines on the end of the tachometer drive gear shaft for pitting, burring, and wear. Check the fit of the tachometer drive gear shaft in the oil pressure pump drive shaft. (Refer to the applicable Table of Limits.)

Inspect the tachometer drive gear housing cover for cracks, and for scratching, nicking, scoring, and warping of the finished surfaces. Inspect the studs for straightness, tightness, and thread condition. Inspect the electric tachometer drive shaft rear bushing for scratches, burrs, tightness in the cover, and wear. Check the fit of the electric tachometer drive shaft in the bushing. (Refer to the applicable Table of Limits.)

Inspect the mechanical tachometer drive shaft housing for cracks, nicks, scoring, and warping of the finished surface, and condition of the threads. Inspect the bushing for nicks, scratches, tightness in the housing, and wear. Check the fit of the mechanical tachometer drive shaft in the bushing. (Refer to the applicable Table of Limits.) Inspect the electric tachometer substituting cover for cracks and nicking, scoring, and warping of the finished surface.

**DUAL ACCESSORY DRIVE HOUSING AND COVER** Inspect the dual accessory drive housing and cover for cracks, and for nicking, scoring, and warping of the finished surfaces. Inspect the studs for straightness, tightness, stretching, and condition of the threads. Inspect all oil passages for cleanliness and freedom from obstruction. Inspect all plugs and plug holes for thread condition.

Inspect the intermediate drive shaft bushing, the idler gear bushing, and the upper and lower drive gear bushings in the dual accessory drive housing and cover for scratches, nicks, tightness in the housings, and wear. Check the fit of the respective shafts in the bushings. (Refer to the applicable Table of Limits.)

Inspect the upper and lower drive substituting covers for cracks and nicking, scoring, and warping of the finished surface.

**DUAL ACCESSORY DRIVE GEARS** Inspect the dual accessory driving gear, the dual accessory drive idler gear, and the upper and lower drive gears for cracks, pitted, chipped, burred, and worn teeth and splines, and burred, scratched, galled, and worn journals. Inspect the intermediate gear for pitted, chipped, burred, and worn teeth, and for mutilation of the threads in the attaching screw holes. Inspect the attaching screws for thread condition. Inspect the tongue coupling installed in the upper and lower drive gear shafts, if used, for tightness in the shafts and for mutilation of the slot.

# CRANKSHAFT, MASTER ROD, AND ARTICULATED RODS

**CRANKSHAFT FRONT END** Inspect the crankshaft front end for cracks. Carefully inspect all surfaces of the crankshaft front end for scratches, nicks, and scores. Inspect the crankpin for burring, scratching, scoring, and picking-up, particularly in the location of the crankpin oil hole and the fillet at the front end of the crankpin. Inspect the crankpin for evidence of burning. Inspect for an out of round condition at both front and rear of the crankpin, using a micrometer, checking the crankpin diameter in each case at two locations 90 deg. apart. Inspect the clamping surface at the rear of the crankpin for scratches, burrs, chafing, and evidence of turning of the crankshaft rear on the crankpin.

Inspect the rear face of the front crankshaft cheek adjacent to the crankpin fillet for scratching, scuffing, and roughness of the highly polished finish on its surface. It is recommended that a finish of 13 to 15 micro-inches be maintained on this surface, which contacts the master rod end seal disk in order to prevent mutilation and excessive wear of the disk. In appearance, a finish of 15 micro-inches is glossy, nearly mirror-like, and it is perfectly smooth to the touch. A reference block having a 15 micro-inch finish may be procured under Tool No. 801762, for comparison.

Inspect the front and rear propeller shaft bushing journals for scratches, scuffing, galling, and wear. Inspect the crankshaft front main bearing journal for scratching and scoring caused by removal of the bearing inner race, which is a tight fit on the crankshaft. Check the outside diameter of the crankshaft front main bearing journal and the inside diameter of the front main bearing inner race, using micrometers, to insure that the proper fit is obtained. (Refer to the applicable Table of Limits.)

Inspect the threads at the reduction driving gear nut location for burrs and mutilation. Inspect the splines at the reduction driving gear location for pitting, burring, scoring, galling, and wear.

Inspect all oil passages in the crankshaft front end for cleanliness and freedom from obstruction. Inspect the crankpin oil tube in the interior of the crankpin for tightness.

Inspect the crankshaft front end bushings, through which the counterweight pins pass, for pitting, chafing, scoring, picking-up and excessive wear on the ends and inside diameter, and for tightness in the crankshaft cheek. Inspect the front counterweight for cracks, nicks, scratches and scores. Inspect the front counterweight bushings for tightness in the counterweight, pitting, chafing, scoring, picking-up, and excessive wear on the ends and inside diameter. Inspect the front counterweight pins for cracks, scratches, pitting, scuffing, pounding, and wear. Inspect the front counterweight stop for cracks, scratches, and nicks, and inspect the bolts and nuts which attach the stop to the crankshaft cheek for thread condition.

Inspect the breather tube, if used, for cracks, burrs, scratches, scores, and cleanliness of the oil holes and inside diameter. The front support of the tube should be inspected with the use of a magnifying glass to determine the condition of the soldered joint to the tube. Inspect the breather tube rear support or the substituting plug, whichever is used, for cracks, burrs, and scores, and inspect the lock screw for thread condition.

Inspect the crankpin front plug for cracks, burrs, and scores, and inspect the lock screw for condition of the threads.

**CRANKSHAFT REAR END** Inspect the crankshaft rear end for cracks. Carefully inspect all surfaces of the crankshaft rear end for scratches, nicks, and scores. Inspect the inside diameter of the crankpin hole for scratches, burrs, and chafing.

Inspect the front face of the crankshaft rear adjacent to the crankpin hole for scratching, scuffing, and roughness of the highly polished finish on this surface. It is recommended that a finish of 13 to 15 micro-inches be maintained on this surface, which contacts the master rod end seal spacer, in order to pre-

vent mutilation and excessive wear of the spacer. Use reference block (Tool No. 801762) for comparison to determine if the finish on this surface is satisfactory.

Inspect the crankshaft rear main bearing journal for scratching and scoring caused by removal of the tight-fitting bearing inner race. Check the outside diameter of the crankshaft rear main bearing journal and the inside diameter of the rear main bearing inner race, using micrometers, to insure that the proper fit is obtained. (Refer to the applicable Table of Limits.)

Inspect the threads at the crankshaft rear main bearing nut location for burrs and mutilation. Inspect the rear main bearing nut for burred or mutilated threads, and inspect the hexagonal faces of the nut for burring and mutilation. Inspect the rear main bearing nut lock screw for general condition.

Inspect the internal splines in the recess in the crankshaft rear for pitting, burring, scoring, and wear. Inspect the accessory drive and starter shaft coupling for cracks and for pitting, burring, scoring, and wear of the external and internal splines.

Inspect the crankshaft rear clamping cap screw for cracks and for burred or mutilated threads. Inspect the cap screw washer for cracks and galling on both faces.

Inspect the bronze crankshaft rear end bushings, which accommodate the floating steel bushings, for pitting, chafing, scoring, picking out, and wear on the ends and inside diameter, and for tightness in the crankshaft rear. Inspect the floating steel bushings for cracks, pitting, chafing, scoring, picking-up, and excessive wear on the ends and both inside and outside diameters. Check the fit of the floating bushings in the bronze bushings, using a feeler gage. (Refer to the applicable Table of Limits.) Inspect the rear counterweight for cracks, nicks, scratches, and scores. Inspect the rear counterweight bushings for tightness in the counterweight, pitting, chafing, scoring, picking-up, and excessive wear on the ends and inside diameter. Inspect the rear counterweight pins for cracks, scratches, and pitting, scuffing, pounding, and wear. Inspect the rear counterweight stop for cracks, scratches, and nicks, and inspect its attaching bolts and nuts for thread condition.

**CRANKSHAFT FRONT AND REAR MAIN BEARINGS** Inspect the crankshaft front and rear main bearing rollers and races, using a magnifying glass, to determine if there are any cracks and if the surfaces are pitted or galled. Inspect the retainers for wear and cracks. The presence of any one of these conditions warrants replacement of a bearing. Do not inspect the crankshaft main bearings by the magnetic type inspection method or by the use of etching fluid. (Refer to the subtitle ANTIFRICTION BEARINGS included at the beginning of this chapter.)

**MASTER ROD** Inspect the master rod for cracks, scratches, nicks, and burrs. Inspect the rear face of the master rod hub for scratching, scuffing, and roughness of the highly polished surface which contacts the end seal spacer. Compare the finish on this surface with the 15 micro-inch reference block (Tool No. 801762). Inspect all oil passages in the master rod for cleanliness and freedom from obstruction.

Inspect the piston pin bushing in the master rod for cracks, burrs, scratches, galling, wear, and tightness in the rod. Check the fit of the proper piston pin in the piston pin bushing in the master rod. (Refer to the applicable Table of Limits.)

Inspect the master rod bearing for cracks, scoring, overheating, flaking of the bearing material, fatigue cracks, foreign material in the bearing, and high spots in the bearing inside diameter. Order replacement of a bearing of which inspection shows any of the above conditions to be present. If no more than five very light scratches are found, and none of the other conditions exist, the bearing is usable. Overheating is evidenced by a red-orange color, possibly streaked with lead from the bearing lining. Fatigue cracks are seen as many short, irregular cracks running parallel to the bearing bore. Small gas holes in the bearing are permissible. Inspect the bearing also for tightness in the rod, condi-

tion of the splines at the front end, and wear of the inside diameter. Check the fit of the crankpin in the bearing. (Refer to the applicable Table of Limits.)

Check the horizontal alignment of the piston pin bushing bore in the master rod with the master rod bearing bore in the following manner: Insert one of the following bars (Tool No. 83568, 84302, 800806, 84254, 800807) in the piston pin bushing bore, and one of the following bars (Tool No. 83562, 84253) in the master rod bearing bore. Select the bars according to size of bushing and bearing bore. Install the master rod in the alignment checking fixture (Tool No. 83552), permitting the rod to hang freely, supported by the bar through the piston pin bushing hole resting on the V-blocks of the fixture. Using a dial indicator supported on a surface gage, measure the height of the bar through the master rod bearing bore at a point three inches (76.2 mm) on either side of the center line of the rod. See figure 149. The misalignment of the piston pin bushing and master rod bearing bores, checked in this manner, should be no greater than .004 inch (.10 mm) in six inches (152.4 mm). Check the master rod for vertical alignment while the rod is supported in the fixture by measuring the clearance between one end of the bar which is inserted through the master rod bearing bore and one rail of the fixture, when the other end of the bar is contacting the other side rail. See figure 150.

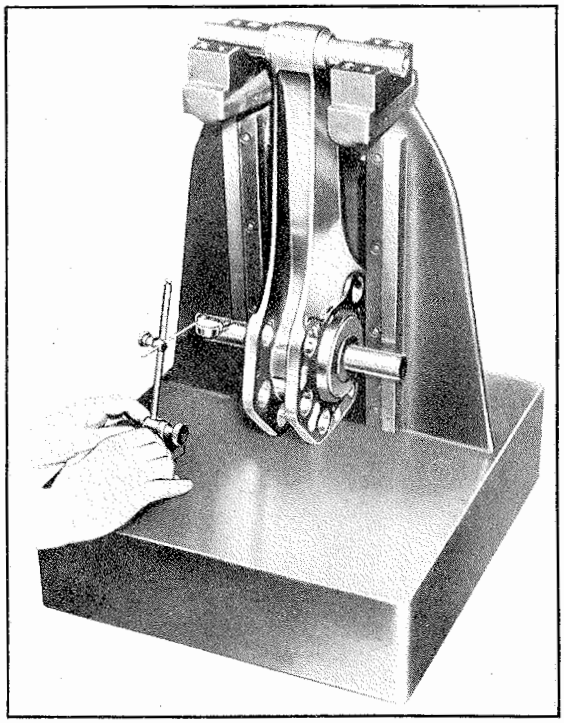


**Fig. 149. Checking Master Rod Horizontal Alignment**

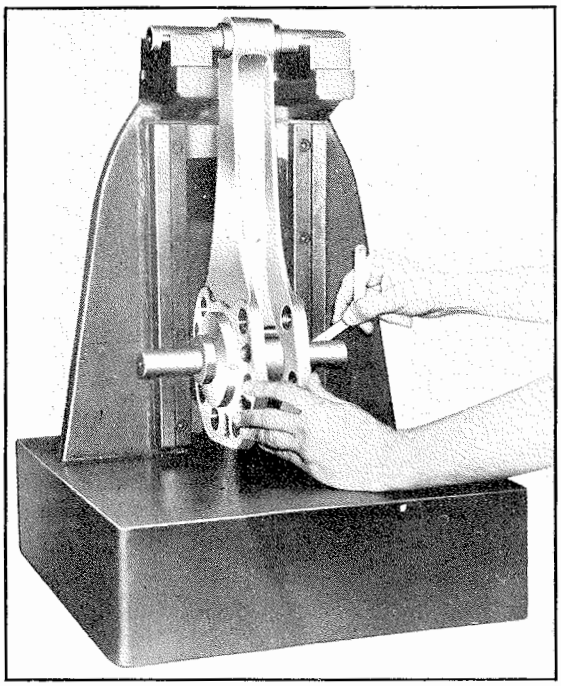


**Fig. 150. Checking Master Rod Vertical Alignment**

The master rod misalignment checked in this manner, should be no greater than .010 inch (.25 mm) in six inches (152.4 mm).

Inspect the knuckle pin holes in the flanges of the master rod for scratches and galling, caused by installation and removal of the knuckle pins. Inspect the inside surface of both flanges adjacent to the knuckle pin holes for galling and chafing caused by the articulated rods.

Inspect the knuckle pin locking plate for cracks, burrs, condition of the splines, bending of the lugs, and cleanliness of all oil passages. Inspect the knuckle pin lock screws for cracks, condition of the threads, and cleanliness of the oil holes. Inspect the master rod end seal disk and spacer for cracks, mutilation, wear, burrs, scores, and flaking of the plating or bearing material. Inspect the end seal spring for proper tension. To do this,

place the spring on a bench or horizontal surface. Place a flat plate over the spring and place weights on the plate. Determine the total weight which is required to compress the spring to .32 inch (8.13 mm), measured from the bench to the under side of the plate when the plate is exactly horizontal.

**ARTICULATED RODS** Inspect the articulated rods for cracks, scratches, nicks, burrs, and bending. Do not use nor attempt to straighten a bent rod. Inspect the piston pin bushing and the knuckle pin bushing in each rod for cracks, burrs, scratches, galling, wear, and tightness in the rod. Split-type piston pin and knuckle pin bushings are used in the connecting rods, and the split in these bushings should not be mistaken for a crack. Check the horizontal alignment of the piston pin bushing bore and the knuckle pin bushing bore in the articulated rods, and check the articulated rods for vertical misalignment, in the same manner as the same check is made on the master rod. Use for this check fixture (Tool No. 83552), bar (Tool No. 83568 or 84302) in the piston pin bushing bore, and bar (Tool No. 83569 or 84304) in the knuckle pin bushing bore. Check the fit of the piston pins and knuckle pins in their respective rods. Refer to the applicable Table of Limits.

## CYLINDERS AND PISTONS

**CYLINDERS** Inspect the rocker box cover parting surfaces and the exhaust pipe flange mounting pad on all cylinder heads for scratches and nicks and for high spots around the studs. Inspect the studs in these mounting pads for straightness, tightness, stretching, and condition of the threads. Inspect the rocker arm bolt bosses in all rocker boxes for cracks, and for nicks and burrs in the spherical washer locations. Inspect the rocker arm bolt bushings for wear on the inside diameter and for tightness in the bosses. Inspect the intake pipe flange mounting pad for scratches and nicks and high spots around the screw bushings. Inspect the intake pipe flange attaching screw bushings in the mounting pad, and inspect the air deflector attaching screw bushings in the outside of the rocker boxes and in the intake pipe flange mounting pad, for mutilation of the threads and for tightness in the cylinder head.

Carefully inspect all cylinder heads visually, both internally and externally for cracks. Order replacement of any cylinder in which the head may be found to be cracked. Inspect the cylinder heads for cracked or broken fins. It is permissible to rework cracked or broken fins by profiling to the depth of the crack provided the crack does not extend into the dome of the cylinder head, and provided the total amount of fin metal removed in this manner does not exceed 14 square inches (84 sq. cm.) per cylinder. Order replacement of any cylinder in which a fin crack is found to extend into the cylinder head dome, or in which more than 14 square inches (84 sq. cm.) of fin metal must be removed to repair cracked or broken fins.

Inspect the exhaust and intake valve guides for tightness in the head, backing out, cracks, and scratching or scoring of the inside diameter. Inspect the location at the inner end of the exhaust valve guide and the adjacent part of the valve guide boss in the exhaust port for burning and pocketing. Inspect the inside diameter of the valve guides for wear, out of round, and bell-mouthing at the ends, using the flat plug gages (Tool No. 82664 for exhaust valve guides and Tool No. 800574 for intake valve guides.) Make this check at both ends of the valve guide. The gages are designed just larger than the maximum permissible diameters. If it is possible to insert the gage in the guide, the guide should be replaced. Make this check at two locations 90 deg. from each other, at each end of the guide, to indicate an out-of-round condition.

Inspect the exhaust and intake valve seat inserts in all cylinders for pitting, burning, and concentricity with their valve guides. Regrind or replace all valve seat inserts which are excessively pitted or burned. An insert which is pitted to such an extent that it cannot be fitted for further use by grinding must be replaced.

If the bluing gage (Tool No. 800250 for ex-

haust valve seats or Tool No. 800249 for intake valve seats) is used to check concentricity, insert a feeler gage between the seat and the gage at a point diametrically opposite from the point of contact between the seat and the gage. If the clearance measured in this manner is greater than .0075 inch (.190 mm), it is recommended that a new valve guide be installed.

Inspect the condition of the threads in the spark plug inserts in all cylinders.

Perform an air test on all cylinders to inspect for leaks. Install dummy spark plugs (Tool No. 82447) in the cylinder being tested, and a dummy intake valve (Tool No. 801366). Insert plug (Tool No. 82306) in the exhaust valve guide. Install the exhaust pipe flange mounting pad cover plate (Tool No. 801364) and gasket (Tool No. 801365) on the mounting pad, tightening four nuts and washers on the exhaust pipe flange studs to make an air-tight connection. This cover plate is provided with a fitting in which an air pressure line is installed. Install a gasket under the cylinder flange and install the cylinder in the air test fixture (Tool No. 802146). Adjust the three clamps over the flange to lock the cylinder securely in place in the fixture. Using a small paint brush, coat the area between the wide flange at the base of the cylinder head and the top cylinder head fin, and also around the spark plug inserts in the cylinder head, with a mixture of equal parts of engine oil and kerosene. Apply 90 pounds per square inch (6.33 kg./sq.cm.) air pressure into the cylinder head. See figure 151. Leaks are evidenced by bubbling of the oil. Order replacement of a cylinder in which a leak is found in the joint between the cylinder head and barrel. If a leak is found around the spark plug insert, order replacement of the insert.

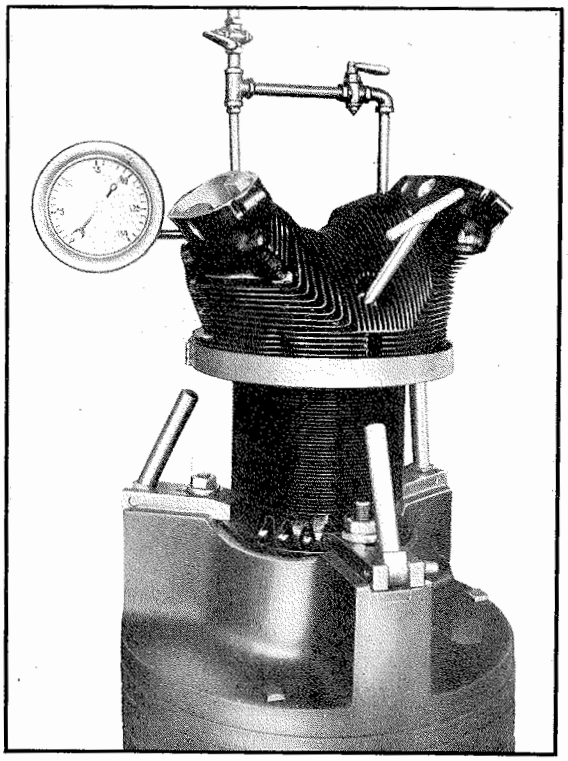


**Fig. 151. Air Testing Cylinder for Leaks**

Inspect the cylinder barrel for bent, cracked, and broken skirts and fins. Replace any cylinders with a bent or cracked skirt, or with barrel fins broken at the root of the fin.

Inspect the cylinder mounting flange for cracks, nicks, and warping. Failure of cylinder hold-down cap screws may occur if cylinders having warped flanges are used. Inspect the cylinder hold-down cap screws for cracks and for mutilated threads and hexagonal heads.

Inspect the inside diameter of the cylinder barrel in all cylinders for corrosion, scores, ring wear, minimum and maximum diameter, out of round, and taper. Corrosion is evidenced by rust or pit marks. Ring wear is evidenced by ridges or grooves near the top and bottom of the barrel, at the ends of the piston travel.

Use cylinder bore gage (Tool No. 800641) to measure the minimum and maximum diameter of the cylinder bore, and to check the bore for out of round and taper. This gage is used in connection with a master ring gage (Tool No. 84757) which has an inside diameter equal to the cylinder bore standard diameter of 6.125 inches (155.575 mm). Insert the cylinder bore gage in the master ring gage, and set the indicator to zero. Insert the cylinder bore gage in the cylinder in the plane of the cylinder mounting flange so that the indicator spindle contacts the thrust and antithrust sides of the cylinder wall. See figure 152. Take a reading at this position, then

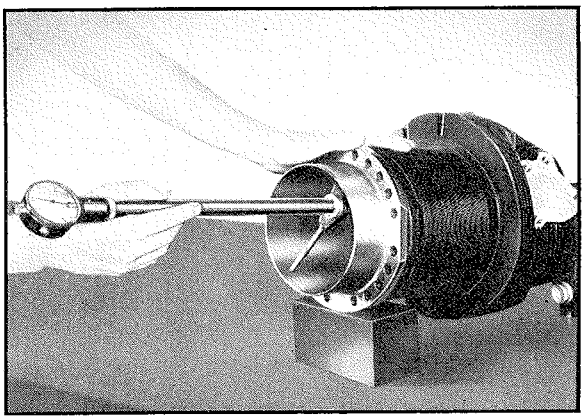


**Fig. 152. Checking Cylinder Bore Dimensions**

turn the gage and take another reading 90 deg. from the first position. The difference between these two readings is equal to the cylinder bore out of round in this plane. Repeat this procedure in a plane approximately half way up the cylinder barrel, and again at the head end of the cylinder barrel, where the ring wear is greatest.

Record the minimum and maximum diameters of the cylinder bore, and the maximum out of round in the three planes checked. Subtract the maximum reading obtained at the head end of the cylinder bore from the minimum reading obtained at the flange end to determine the taper of the cylinder bore. (Refer to the Table of Limits for the maximum permissible limits of cylinder bore out of round, wear, and taper.) Cylinders which are scored on the inside diameter or which are worn beyond the permissible limits must be reground to an oversize bore, or returned to the factory for the installation of new cylinder barrels. NOTE: Cylinders used in C9GC engines are provided with a choke bore at the head end of the barrel. This end of the barrel has a smaller diameter than other parts of the barrel to provide for ring wear, which is greatest in this location. Consequently, at the first or second overhaul of a new engine or of an engine using new cylinders, the maximum diameter of the choke bore may be less than the minimum inside diameter at the mounting flange location. This condition is normal for choke bore cylinders. Cylinder bore taper is undesirable only when the diameter at the head end of the barrel is larger than the diameter of other parts of the barrel, indicating excessive ring wear at the head end.

**VALVES** Inspect exhaust and intake valves for cracks. Do not inspect exhaust valves for cracks by the magnetic type method of inspection. Inspect the valve head, face, stem, and tip for pitting, scores, burning, and wear. See figure 153, which shows the area in which valve stem pitting is objectionable. Inspect the edges of the split lock groove for wear, burrs, and chipping. Measure the valve stem diameter, using a micrometer, to determine if the proper fit of the valve in its guide is obtained. (Refer to the applicable Table of Limits.)

Inspect the valve faces for warping. To do this, place the valve horizontally on a V-block on a square surface, so that the valve head projects over the end of the block, and the valve tip contacts a stop at the other end of the block. Install a dial indicator in a surface gage, and adjust the indicator finger to contact the valve face. Turn the valve, keeping the tip in contact with the stop, and observe

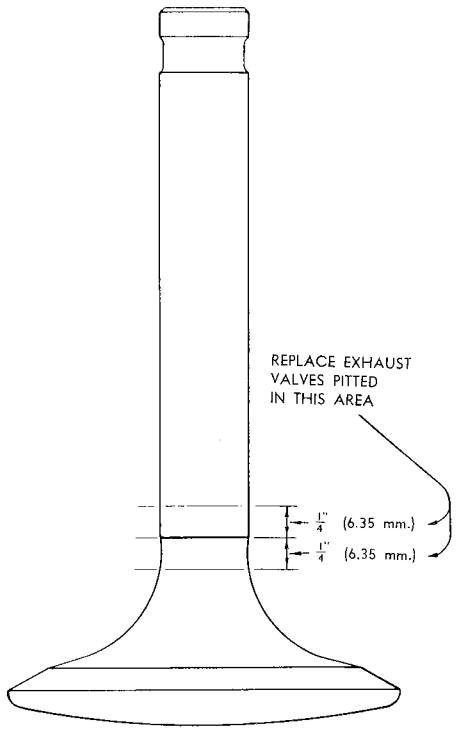



**Fig. 153. Valve Stem Area Where Pitting Is Objectionable**

the runout on the indicator. A warped valve head will cause burning of the valve face.

Inspect exhaust valves for minimum face diameter, tip wear, and stretch using the exhaust valve limit gage (Tool No. 800353). Push the pointed pin on the gage against the spring, and place the valve to be checked in the V-blocks of the gage so that the locating pins in the gage contact the upper radius of the lock groove in the valve stem. Release the pointed pin, allowing the point to contact the underside of the valve head adjacent to the inner diameter of the valve face. The minimum permissible diameter of the valve face is indicated by the point of the pin. The inner face diameter must fall outside of the point of the pin. The limit of wear or refacing of the tip of the valve stem is indicated by the end of the gage body. The tip of the valve stem must fall outside of, or be flush with, the end of the gage body. The maximum permissible valve stretch is indicated by the upper end of the pin on the gage relative to the end of the gage body. The end of the pin must fall outside of, or be flush with, the end of the gage body. See figure 154.

CAUTION: Exhaust valves are filled with sodium, which is inflammable in the presence of water. To insure against fire and possible personal injury as a result of this condition, extreme care should be exercised when disposing of exhaust valves which are not fit for further use. Purchasers of scrap equipment should be advised of this condition.

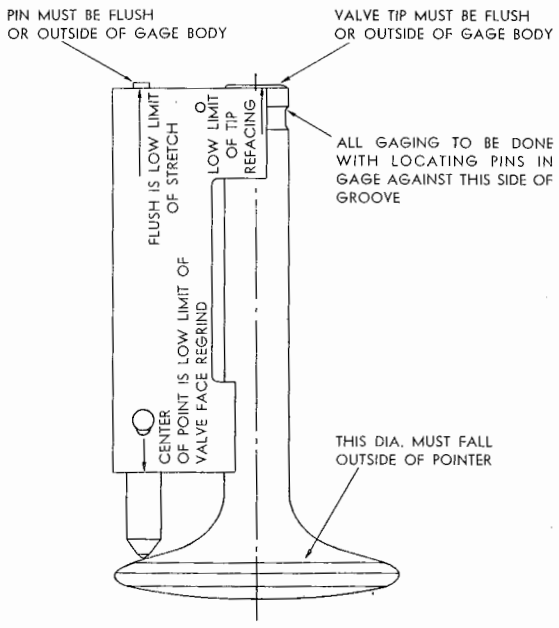

PIN MUST BE FLUSH OR OUTSIDE OF GAGE BODY
VALVE TIP MUST BE FLUSH OR OUTSIDE OF GAGE BODY
FLUSH IS LOW LIMIT OF STRETCH
LOW LIMIT OF TIP REFACING
ALL GAGING TO BE DONE WITH LOCATING PINS IN GAGE AGAINST THIS SIDE OF GROOVE
CENTER OF POINT IS LOW LIMIT OF VALVE FACE REGRIND
THIS DIA. MUST FALL OUTSIDE OF POINTER

**Fig. 154. Checking Exhaust Valve Using Limit Gage**

Inspect intake valves for minimum face diameter and tip wear using the intake valve limit gage (Tool No. 800353), in the same manner as described for exhaust valves. It is not necessary to inspect intake valves for stretch.

Inspect the split locks for cracks, burrs, and wear. Inspect the valve springs for cracks and for proper tension. See figure 155. Reject any spring whose tension is not within the specified limits. (Refer to the applicable Table of Limits.) Inspect the valve spring washers for cracks, burrs, and wear.

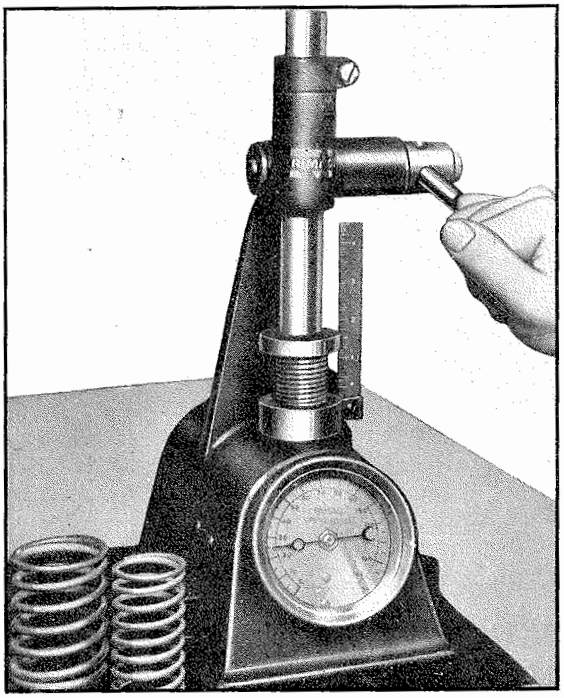


**Fig. 155. Testing Valve Spring Tension**

**PISTONS** Inspect all pistons for cracks, particularly in the location of the piston pin bosses, ring lands, and skirts. Inspect the piston heads for burning. Inspect the ring grooves for cleanliness, burrs, and for cracked or chipped edges. Inspect the drilled holes in the fourth and fifth ring grooves for

cleanliness. Inspect the ring lands and the piston skirts for scratches, scores, and nicks.

Measure the diameter of the pistons using a micrometer located midway between the bottom ring groove and the fifth ring groove, on the thrust and anti-thrust diameter. Compare this diameter with the diameter of the cylinder bore to determine if the proper fit of the piston in its cylinder is obtained. (Refer to the applicable Table of Limits.)

Inspect the piston pin holes in the piston for scratches, scores, and wear. Check the fit of the piston pin in these holes. (Refer to the applicable Table of Limits.) Inspect the piston pin retainer grooves for worn edges and general condition. NOTE: The transverse depressions worn in the retainer grooves by the coils of the spring retainers are normal, and are not dangerous unless the depressions are worn too deep. The allowable depth of these depressions prior to the rejection of a piston as a result of this condition is one-half the diameter of the wire of the coil spring retainer. Do not attempt to remove these depressions by polishing or machining the retainer grooves.

Inspect the piston pin by means of the magnetic-type inspection. Examine the outside diameter for any magnetic indications. Inspect for scoring. Redip the pin in the magnetic solution to inspect the inside diameter. If necessary, use a dental mirror to inspect the inside of the pin. Any pins having questionable indications should be returned to the factory for inspection. Check for out of round by using a micrometer and inspect for straightness using a dial indicator at the center of the pin while turning the pin in V-blocks. See figure 156.

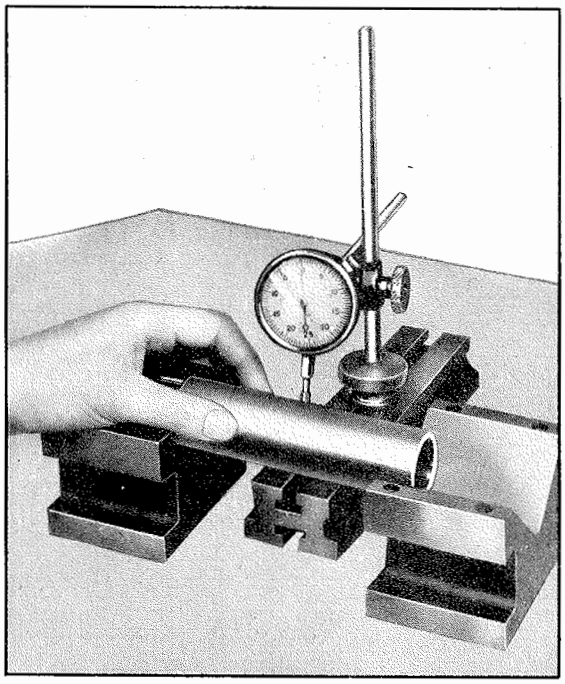


**Fig. 156. Checking Piston Pin Alignment**

## ROCKER BOX COVERS, ROCKER ARMS, PUSH RODS, AND PUSH ROD HOUSINGS

**ROCKER BOX COVERS** Inspect all rocker box covers for cracks and for scratching, burring, and warping of the parting surface.

**ROCKER ARMS** Inspect all rocker arms for cracks. CAUTION: Remove the rocker arm bearing before inspecting a rocker arm by the magnetic-type method of inspection.

Inspect the radius between the rocker arm hub and the roller arm for scratches, nicks, and chafing. The presence of any of these conditions is an indication that interference is occurring between the rocker arm and the valve spring upper washer or valve spring. Carefully inspect for cracks in this location. Another check should be made at assembly of the rocker arms in the cylinders to insure that no interference exists at this location. Instructions for making this check are included in the chapter entitled FINAL ASSEMBLY AND TIMING OF ENGINE, under the subtitle ROCKER BOX COVERS, ROCKER ARMS, PUSH RODS, AND PUSH ROD HOUSINGS.

Inspect the rocker arm rollers for flat spots on the outside diameter, chipped edges, cracks, and pitting. Check the end clearance of the roller and the roller hub in the yoke of the rocker arm. (Refer to the applicable Table

of Limits.) Check the wear of these parts by hand, moving the roller at right angles to the pin. Inspect the pin for tightness in the arm.

Inspect the oil passages in the rocker arms for cleanliness.

Inspect the bearing bore in the rocker arms for excessive scratching, scoring, galling, and wear. Measure the diameter of the bearing bore and the outside diameter of the bearing outer race, using micrometers, to determine if the proper fit is obtained. (Refer to the applicable Table of Limits.)

Inspect the rocker arm threads at the adjusting screw and clamping screw locations for burring and general condition.

Inspect the adjusting screws and clamping screws for cracks and thread condition. Inspect the adjusting screws also for wear of the spherical socket, nicks, and burrs on the flange and screwdriver slot, and cleanliness of the oil hole.

Inspect the rocker arm bearings in accordance with instructions included at the beginning of this chapter under the subtitle ANTI-FRICTION BEARINGS. It is not necessary to disassemble bearings to make this inspection unless spinning the outer race by hand while holding the inner race indicates that the bearing runs rough or jerkily. If the bearing is found to run rough, disassemble the bearing to determine whether the cause of this condition is dirt or wear. If the bearing is dirty, clean and reassemble it. If the roughness is due to wear of the races, discard the bearing.

Inspect the rocker arm bolts for cracks, nicks, wear, and condition of the threads.

**PUSH RODS** Inspect all push rods for cracks, bending, and cleanliness of the oil passage. Inspect the ball ends for cracks, looseness in the rod, and excessive wear. Do not attempt to remove the ball ends.

**PUSH ROD HOUSINGS** Inspect the push rod housings for cracks and dents. Inspect for indications of push rod interference. Inspect the hose clamps for cracks and condition of the bolts and nuts.

## INTAKE PIPES, AIR DEFLECTORS, OIL SUMP

**INTAKE PIPES** Inspect intake pipes for cracks and dents. Order replacement of a cracked or mutilated intake pipe. Inspect the intake pipe flange for cracks, nicks, burrs, and condition of the finished surface. Inspect the intake pipe flange attaching screws for thread condition.

**AIR DEFLECTORS** Inspect the cylinder-head and intercylinder air deflectors for cracks, dents, chafing, tightness of the rivets, and thread condition of the attaching screws and nuts.

Inspect the intercylinder air deflectors also for deterioration, tearing, and wear of the neoprene pads. Inspect the intercylinder air deflector upper grommet, plate, and attaching nut for deterioration of the grommet, cracks and mutilation of the plate, and thread condition of the attaching nut. Inspect the intercylinder lower clamp, bolt, nut, and spacer for cracks, bending, and chafing of the clamp, thread condition of the bolt and nut, and cracks and mutilation of the spacer.

**OIL SUMP** Inspect the oil sump for cracks, particularly at the mounting flange locations. Inspect the finished surfaces for chafing, scratches, trueness, and wear. Inspect the scavenge passages in the sump for cleanliness.

Inspect the oil sump strainer plug for condition of the screen and mutilation of the threads and plug head. Inspect the magnetic plug for thread condition and mutilation of the head. Inspect the other oil sump plugs and plug holes for thread condition.

# IGNITION WIRING MANIFOLD

Inspect the inside diameter of all parts of the ignition wiring manifold assembly, particularly at the connections, for nicks, burrs, and abrasions which could tear or otherwise damage the wire cable insulation.

Inspect the halves of the ignition wiring manifold ring and the manifold elbows for cracks, particularly at the outlets and at the mounting bracket locations. Inspect the manifold halves and elbows also for dents, and condition of the threads at the outlets. Inspect the manifold supports and clips for cracks and mutilation.

Inspect the main magneto conduits, the cross-over conduit, and the spark plug conduits for abrasion and separation of the shielding braid, and condition of the threads and knurled and hexagonal union nuts. Inspect the spark plug terminal elbows for cracks and mutilation of the threads and union nut.

Inspect the magneto outlet front flanges and elbows for cracks, condition of the threads, and trueness of the finished surfaces.

## CHAPTER V

# REPAIR AND ASSEMBLY OF SUBASSEMBLIES

THE repair and assembly of engine subassemblies should be accomplished in accordance with instructions in this chapter. Follow closely the recommendations made by the inspector on the INSPECTION FORMS regarding the repair and replacement of parts.

If it is found that the proper repairing of a part necessitates the use of special equipment not available in the overhaul shop, it is recommended that the parts be returned to this factory for repair. All parts returned to the factory for repair should be accompanied by a RETURN NOTICE. (Refer to the section in the Appendix entitled SERVICE STATION MANAGEMENT AND ROUTINE FORMS). Include on the RETURN NOTICE complete information relative to each part. RETURN NOTICE forms are available upon request to the Service Division of the Wright Aeronautical Corporation.

If, during repair or assembly, some defect or unusual condition in a part may be discovered which was not detected during inspection, the inspection report and the part should be returned to the inspector so that he may record its true condition.

## GENERAL REPAIR PROCEDURE

Using crocus cloth and gasoline, clean up light scratches, roughness, and chafing from finished surfaces of engine parts. Specific instances where this is not advisable are given in the text of this chapter.

Remove small nicks, burrs, and scores, and smooth slightly galled and pitted areas from finished surfaces of engine parts by light stoning. After stoning, clean the parts with crocus cloth and gasoline. Specific instances where stoning is not advisable are given in the text of this chapter.

It is permissible to stone gear teeth in some cases to remove slight pitting or galling. Care must be exercised, however, not to stone to a degree which would result in changing the tooth form contour. Excessive stoning of the pitch diameter should be avoided in particular, as this will result in unequal tooth loading when in mesh with the mating gear. Small nicks or burrs on the tooth side faces or on the crest of the tooth may be stoned out provided the tooth form is not changed or that removal of an appreciable amount of metal is not necessary. Any gear which is severely pitted, galled, or has deep nicks or burrs, the removal of which would necessitate excessive stoning, should be discarded and replaced with a new gear. Stoning the faces of the teeth of the propeller shaft stationary reduction gear, pinion gears, and the reduction driving gear is not permitted under any circumstances.

Clean up and dress burred or mutilated threads in all parts, except in cases where it is specifically noted that this is not advisable.

**Do not attempt to repair any broken or cracked part by welding,** except air deflectors. Instructions covering the repair of air deflectors by welding are included in this chapter under the subtitle INTAKE PIPES, AIR DEFLECTORS, OIL SUMP.

Never ream, scrape, bore, or hand-burnish a sintered type bushing. This type of metal is porous in nature, and provides lubrication to the shaft by means of oil seepage through the porous openings. If reaming, scraping, or hand burnishing is attempted, these operations will seal the pores and prevent proper lubrication. Broaching to size is the only recommended method. Any parts fitted with sintered bushings should never be placed in any

solvent cleaning solution as these solutions are highly penetrating and will result in removing the lubricant from the pores of the metal. It is permissible to clean sintered bushings with crocus cloth and gasoline provided these materials are used sparingly to avoid filling the pores. However, upon completion of such cleaning, the bushing and the shaft should be well oiled before assembling the parts.

The use of paraffin to plug oil holes while drilling or reaming, to prevent entrance of chips into the holes and oil passages, is permissible providing the paraffin is not run into the hole in a melted condition. This procedure would block off the oil passage and make removal of the paraffin difficult. If a small ball of paraffin is rolled between the fingers and then used like putty there will be no difficulty in removing the paraffin from the hole.

After drilling or reaming holes, break all the sharp edges remaining around the holes and remove all burrs using a fine stone or crocus cloth.

To obtain alignment of oil holes in a bushing and an engine part when pressing in new bushings, draw a pencil line lengthwise on the bushing through the center of the oil hole parallel with the bore. Do the same with the bushing hole in the engine part. Install the bushing on its press-in plug, align the two pencil marks, and press in the bushing.

Investigation of some parts failures have revealed that they have been caused directly by identification marks improperly placed on the parts by the operator. The incorrect method of marking parts or the marking of parts in certain areas may produce surface cracks which will progress, resulting in complete failure of the part and serious damage to the engine. This applies particularly to highly stressed parts which have been metal stamped or electrically etched. The Wright Aeronautical Corporation will not be responsible for any damage to an engine which may be traced to any marks placed on any steel parts of the engine by the operator either by metal stamping, center punching, or electric etching. Marks placed on certain parts by the factory are placed in definite areas where experience has indicated it will be safe to place them. Other parts are identified through the use of a special etching fluid, Zincograph, 1 and 2, and a rubber stamp. This fluid may be used to saturate an ordinary ink stamping pad and is used with a rubber stamp in the same manner as an ordinary ink stamp pad. After a part is etched the surface should be oiled with engine oil to prevent corrosion. This etching fluid should never be used for etching of steel parts to detect defects.

# PLATING ENGINE BEARINGS AND BUSHINGS

**COMPOUNDING PLATING SOLUTION** The following instructions apply to the compounding of the lead plating solution and to the method for making an analysis of an addition to the solution.

The lead plating solution is composed of the following ingredients:

| Ingredients | Ounces per Gallon of Solution |
|---|---|
| 50 per cent Hydrofluoric Acid | 32. |
| Boric Acid | 14. |
| Basic Lead Carbonate | 20. |
| Pure Fish Glue | 0.025 |

Perform the compounding of the lead plating solution under a hood or near an exhaust fan, since the fumes are irritating. Place the hydrofluoric acid in a lead or hard-rubber-lined tank and add the boric acid crystals a few at a time while stirring the mixture with a wooden paddle. Since heat is generated, allow the mixture to cool. Mix the lead carbonate with sufficient water to form a thin paste and add to the above solution slowly so that it does not effervesce and foam over. Allow the lead sulphate precipitate to settle for at least twelve hours and then siphon off the clear liquid into a glass container. Discard the precipitate and unsiphoned liquid. Dissolve the glue in warm water and add to the clear solution, which may then be stored in the glass container until used.

Do not add water to these ingredients until just before use of the plating solution. Then remove a suitable portion of the concentrate from its container and add sufficient water to bring specific gravity of the solution to 1.17, or measured by the Baume system, 21 degrees. By this addition of water, the volume is increased approximately three times.

In lead plating, some loss of the plating solution occurs as a result of clinging to contacted surfaces (drag-out) and as a result of leakage of the fixture or connections. Replenish the solution as required by the addition of fresh solution of specific gravity 1.17. The addition of fresh solution of specific gravity 1.17 will usually maintain the specific gravity of the original solution within sufficiently close limits. However, if lead plate of an uneven color, or a spongy deposit should be obtained, discard the lead plating solution.

It is recommended that the plating solution be obtained from a chemical laboratory or reputable plating company, since great care and a certain technique are required in preparing the solution. The plating solution will not be supplied by the engine manufacturer. See the section entitled SHOP MATERIALS, in Appendix.

**PLATING MASTER ROD BEARINGS** It is recommended that newly installed master rod bearings be lead plated after finish boring. Refer to subtitle MASTER ROD, for instructions regarding finish boring master rod bearings.

Do not attempt to lead-plate used master rod bearings at engine overhaul. A used bearing may be continued in use in the engine, whether or not it was plated before original installation, if inspection indicates that it is satisfactory for further use.

The proper finish smoothness of master rod bearing surfaces before plating, after boring is 15 to 25 micro-inches. Bearing surface finish may be measured using a profilometer.

A fixture for lead plating master rod bearings is available under Tool No. 800948. See figure 157. This fixture consists of a base or bottom plate, one side of which is counterbored to provide a recess for two rubber gaskets, used to prevent leakage of the plating solution. The bottom plate is also provided with two long studs for clamping the master rod in position and a drilled hole for the plating solution hose connection. The base plate is attached to a wooden bench or table by means of screws or bolts, the hole in the plate being placed directly over a hole drilled in the bench or table.

The fiber top or locating plate is counterbored on both sides to permit its application to various size master rods. The locating plate has a large hole drilled through its center to permit the installation of the plating anode which is secured to the plate by means of two screws located in drilled and tapped holes in opposite sides of the plate.

The master rod is secured in the fixture by means of two hand knobs attached to the two studs in the bottom plate. The master rod is supported at the piston pin end by a wooden block cut to the proper height.

Procure a one-liter or one-quart leveling bottle having an outlet on the bottom to which a rubber tube may be connected. Using a rubber tube, connect the outlet on the bottle to the inlet on the base plate of the fixture. A pinch clamp on the rubber tube which will close off the tube when desired is recommended for use.

A 6-volt storage battery may be used as a current supply. Connect the battery in series with a carbon pile rheostat and a standard 0-10 ampere ammeter. A voltmeter may also be incorporated in the circuit if desired as a check on the current supply. The master rod itself serves as a cathode, or negative electrode, a standard battery clip being used to make the connection to the master rod flange. A pure lead anode, Tool No. 801336, or positive electrode, is installed as shown in the sketch. See figure 157.

Perform the leading plating operation at room temperature by observing the following procedure:

(1) Remove all grease and oil from the bearing surface by washing thoroughly in

trichlorethylene, carbon tetrachloride, or unleaded gasoline.

(2) Rinse the bearing end of the master rod in a solution of Clepo No. 64 cleaner, or its equivalent soap cleaner, heated to 212 deg. F.

(3) Rinse in clean hot water.

(4) Rinse in clean cold water.

(5) Rinse in clean hot water.

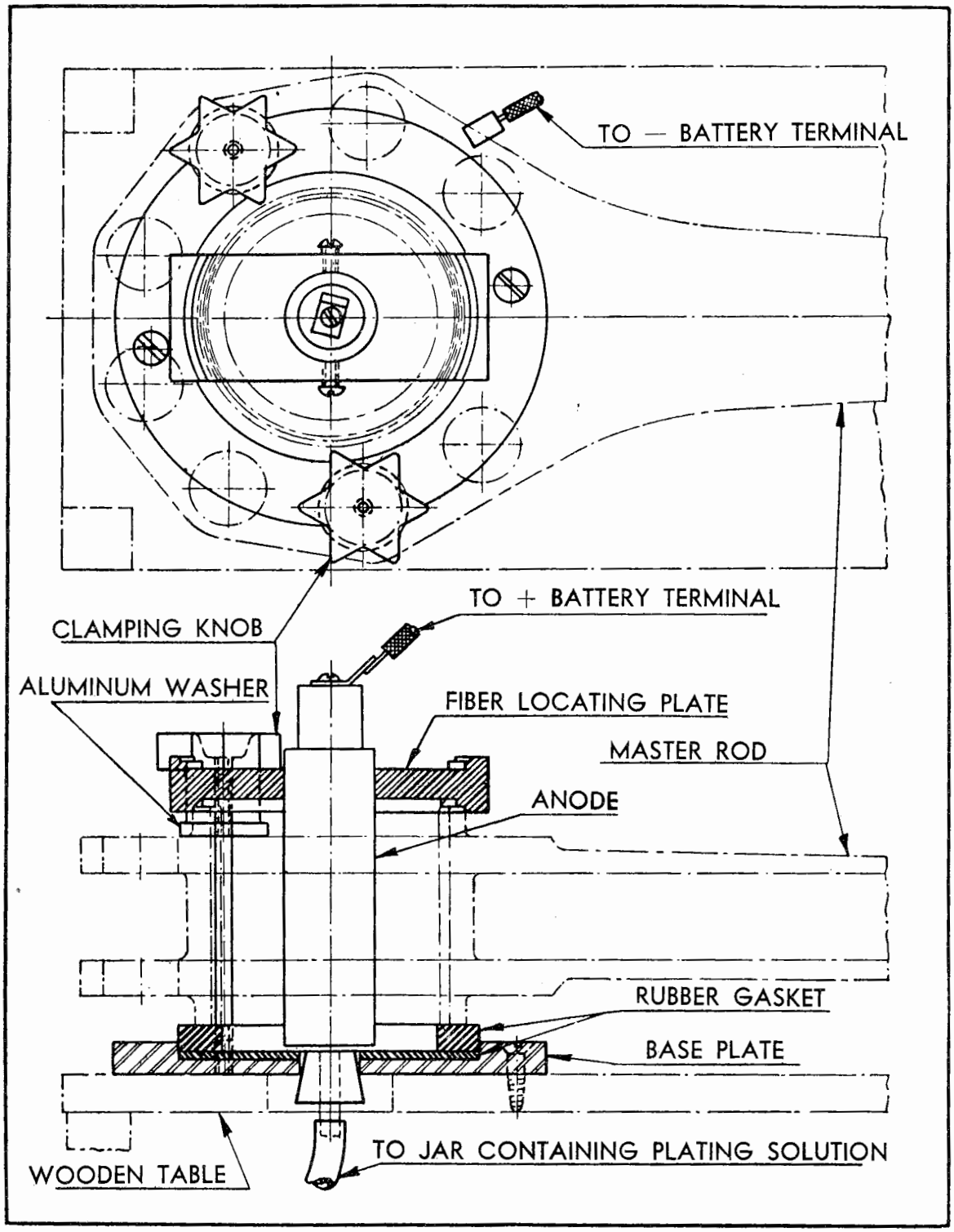



**Fig. 157. Fixture for Plating Master Rod Bearing**

(6) Scrub the bearing surface with powdered pumice and water, using a soft bristle brush.

(7) Rinse in clean cold water.

(8) Blow dry with air hose, but do not turn air blast directly on the bearing surface, as there may be small particles of oil or dirt in air stream. CAUTION: Do not touch surface to be plated after cleaning.

(9) Install the master rod in the lead plating fixture, Tool No. 800948. Place rubber ring gasket over ⅛ inch thick round rubber gasket in base plate recess. Install master rod over the two studs on base plate with splined end of bearing up. Clamp rod to fixture, using aluminum washers and hand knobs. Rest the shank end of rod on a wooden block cut to proper height to support rod in a horizontal position. Place fiber top or locating plate in place with proper locating diameter in position to suit bearing flange diameter. Install lead anode, Tool No. 801336, in locating plate. Adjust position of anode so that it extends approximately ¼ inch through bottom of bearing to insure that entire bearing surface will be plated, taking care that anode does not bottom in fixture, thus cutting off flow of plating solution into fixture. Tighten two round head set screws to hold anode in position, taking care to see that anode is centered in bearing.

(10) Hold the jar of lead plating solution above the level of the master rod and release the pinch clamp, allowing solution to flow into the bearing recess until it is level with the radius at the end of the bearing. Close pinch clamp. Take care that the solution does not come in contact with any part of the rod other than the bearing surface.

(11) Attach the positive side of the electrical circuit to the lead anode and close the circuit by attaching the clip on the negative lead to the master rod flange. Plate at 3.4 amperes for 14 minutes to produce a plate thickness of .0004 inch ± .0001 inch. Adjust the rheostat to obtain the exact amperage and time the plating operating carefully.

(12) Detach the positive lead clip, lower the solution bottle below the level of the master rod, release the pinch clamp and allow the solution to drain back into the bottle.

(13) Remove the rod from the fixture.

(14) Rinse in clean cold water.

(15) Rinse in clean hot water.

(16) Blow dry with air hose.

(17) Dip rod in engine lubricating oil.

Extreme care must be exercised to maintain a chemically clean bearing surface prior to plating in order to obtain an adherent, uniform plate, free from pin holes, blisters and strain. A defective plate can only be safely removed by scrubbing with pumice. If an uneven color of lead plate or a spongy deposit should be obtained, discard the lead plating solution, remove the defective lead plate by scrubbing with pumice, and replate using new solution.

The lead anode, after being used in plating for some time, will be found to be of a smaller diameter than it was originally. Discard a lead anode when its diameter at any point which extends into the bearing is found to be less than 1⅛ inch.

Instructions for the compounding of the lead plating solution and for the maintenance of the proper solution strength will be found at the beginning of this chapter.

The soap solution used for cleaning the bearing may be made up by mixing eight ounces of Clepo No. 64 cleaner to one gallon of water.

Clepo No. 64 cleaner may be purchased from Frederic Gumm Chemical Co. Inc., Kearney, N. J.

**PLATING ARTICULATED ROD KNUCKLE PIN BUSHINGS**

It is recommended that newly installed articulated rod knuckle pin bushings be lead-plated after finish boring. Refer to subtitle ARTICULATED RODS, for instructions regarding finish boring of articulated rod knuckle pin bushings.

Do not attempt to lead plate used knuckle pin bushings. A used bushing may be continued to be used in the engine whether or not it was plated before original installation,

ings may be procured under Tool No. 800975. See figure 158.

This fixture consists of a base or bottom if inspection of the bushing indicates that it is still in good serviceable condition.

A fixture for lead plating knuckle pin bush-

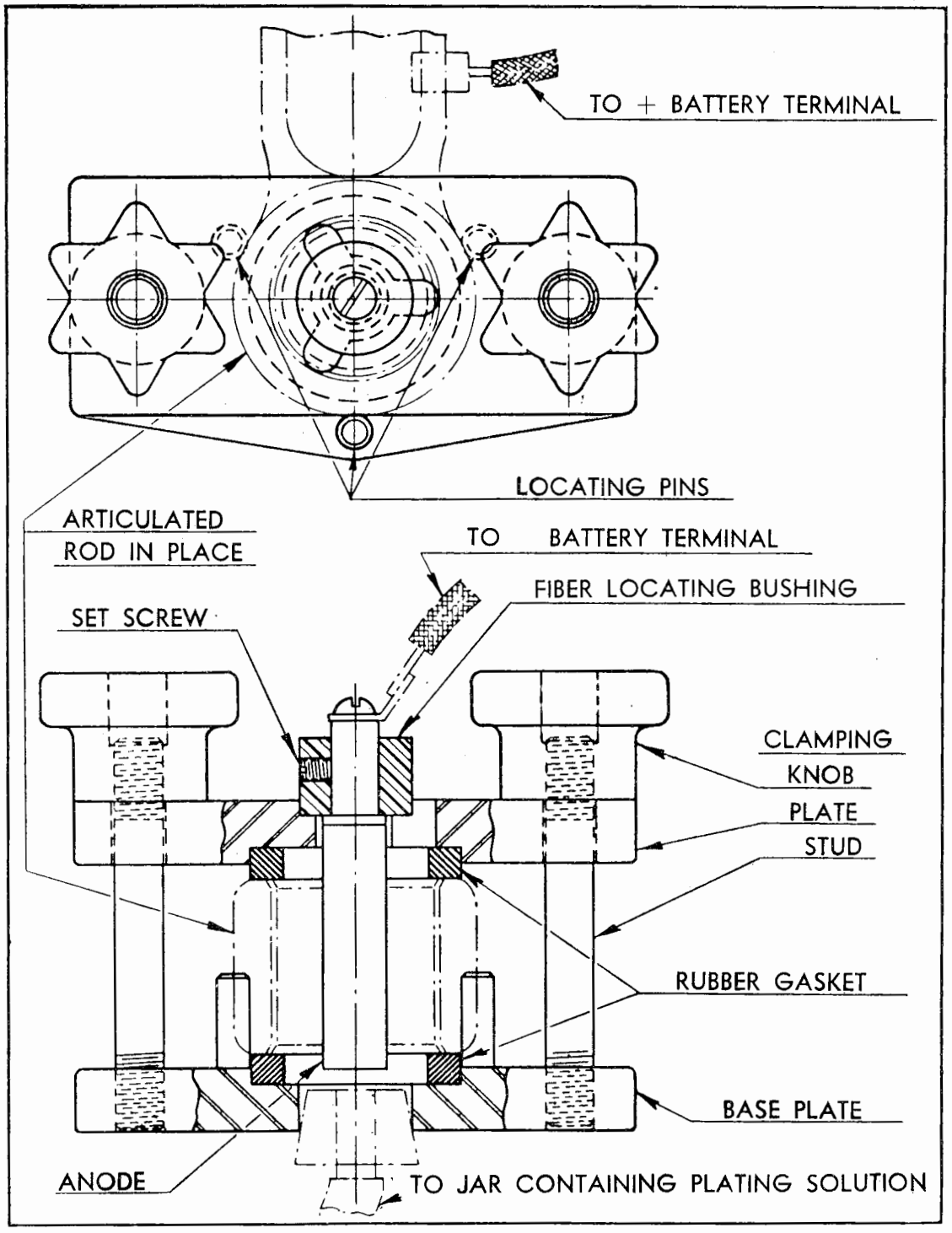



**Fig. 158. Fixture for Plating Articulated Rod Knuckle Pin Bushing**

plate on which the knuckle pin end of the articulated rod is located by means of three locating pins. The bottom plate is also provided with two long studs for attaching the top plate, as well as an opening for inserting the plating solution hose plug. The articulated rod is held in place by means of a top plate placed over two studs screwed into the bottom plate. The top plate is also utilized to carry the plating anode. Two hand knobs attached to the threaded ends of the long studs are used to secure the top plate in position when the articulated rod is installed in the fixture.

Two semihard rubber gaskets are utilized to prevent leakage of the plating solution, one being located in a recess in the bottom plate and the other in a recess in the top plate.

A wooden holding fixture, consisting of a base and two slotted uprights for supporting the articulated rod may be made locally.

A leveling bottle of one quart or one liter capacity, to which a rubber hose and pinch clamp is attached, is utilized for holding the plating solution.

A standard 6-volt storage battery may be used as a current supply. Connect the battery in series with a carbon pile rheostat and a standard 0-10 ampere ammeter. A voltmeter may be used in the circuit if desired, as a check on the current supply. The rod itself serves as a cathode, or negative electrode, a standard battery clip attached to the negative lead being used to make the connection to the rod. A pure lead anode or positive electrode, Tool No. 801337, is installed as shown in the sketch. See figure 158.

Perform the lead plating operation at room temperature, as follows:

(1) Remove all grease and oil from the surfaces to be plated by washing thoroughly in trichlorethylene, carbon tetrachloride or unleaded gasoline.

(2) Rinse the knuckle pin end of the rod thoroughly in a solution of Clepo No. 64 cleaner (eight oz. to one gallon of water), or its equivalent soap cleaner, heated to 212 deg. F.

(3) Rinse in hot water.

(4) Rinse in cold water.

(5) Rinse in hot water.

(6) Scrub the bearing surface with powdered pumice and water, using a soft bristle brush.

(7) Rinse thoroughly in clean cold water. CAUTION: **Do not touch surface to be plated after cleaning.**

(8) Place articulated rod on wooden holding fixture and install plating fixture, Tool No. 800975. Place one rubber gasket on bottom plate of plating fixture and place bottom plate over the knuckle pin end of the articulated rod with the locating pins around the outside diameter. Place the other rubber gasket over end of knuckle pin bushing and install top plate over the two studs on bottom plate. Clamp rod in position with the two hand nuts. See figure 158.

(9) Place plating anode, Tool No. 801337, with fiber locating bushing through the hole in the top plate, allowing the bushing to rest in the counterbore hole. Adjust the anode so that the bottom end extends through, and approximately ⅛ inch below, the knuckle pin bushing. Check to see that the lead anode is centered in the bushing hole.

(10) Connect the lead plating solution bottle to the bottom of the fixture by means of the rubber hose and rubber plugs. Hold solution jar above the level of the rod, release the pinch clamp attached to the hose and allow plating solution to flow into knuckle pin bushing recess around the anode until the surface to be plated is covered. Take care that the solution does not come in contact with any part of the articulated rod other than that to be plated. Tighten the pinch clamp.

(11) Attach the positive side of the electrical circuit to the lead anode and close the circuit by connecting the negative side of the circuit to the articulated rod channel flange by means of the battery clip. Plate at .5 (½) ampere for 8¼ to 13¾ minutes to obtain a plate thickness of .0003 inch to .0005 inch. Adjust the rheostat to obtain the exact amperage specified above and time the plating operation carefully.

(12) After plating, detach battery clip from rod. Lower solution bottle below level of rod,

release pinch clamp and allow solution to drain back into bottle. Tighten pinch clamp on the hose.

(13) Remove the anode and the locating plate from the rod. Remove the rod from the fixture.

(14) Rinse rod thoroughly in hot water.

(15) Blow dry with air hose, but do not turn air blast directly on bearing surface, as there may be small particles of oil or dirt in the air stream.

(16) Remove all acid stains on outer diameter of rod with small felt wheel.

(17) Dip rod in clean lubricating oil.

Extreme care must be exercised to maintain a chemically clean bearing surface prior to plating in order to obtain an adherent, uniform plate, free from pin holes, blisters and strain. A defective plate can only be safely removed by scrubbing with pumice. If an uneven color of lead plate or a spongy deposit should be obtained, discard the lead plating solution, remove the defective lead plate and replate using new solution.

Instructions for the compounding of the lead plating solution and for the maintenance of the proper solution strength will be found at the beginning of this chapter.

## ENAMEL FINISHING

**BLUE-GRAY ENAMEL** This finish is used on the following parts: Crankcase front section, oil sump, oil pump, supercharger front housing, supercharger rear housing, supercharger rear housing cover and dual accessory drive housing.

Complete removal of the old enamel is in many instances unnecessary if the condition of the original enamel is good except for chipped areas. This can be determined by testing the finish for adhesion to the surfaces and if it is not brittle and does not chip off, the part should be refinished as follows:

Clean thoroughly using a Varsol spray.

Sandpaper the chipped areas using No. 340 sandpaper and use No. 320 sandpaper to smooth the remaining surfaces to obtain a good bonding surface. The sandpaper may be used either wet or dry.

After the desired results are obtained, clean thoroughly with a Varsol spray.

Apply a light coat of Zinc Chromate primer to the chipped areas being careful not to coat the machined parting surfaces.

Zinc Chromate primer may be made up by mixing 1½ parts of Toluol thinner W.A.C. Specification No. 5865 to 1 part of Zinc Chromate (package material) W.A.C. Specification No. 5850. Refer to section in Appendix entitled SHOP MATERIALS.

Place the part in a flameless oven at 225 deg. F. (106 deg. C.) and bake for 2 hours, or at 250 deg. F. (120 deg. C.) for 1½ hours.

Apply the first coat of Blue-Gray enamel and place the part in a flameless oven at 225 deg. F. (106 deg. C.) for 2 hours or 250 deg. F. (120 deg. C.) for 1½ hours.

Blue-Gray enamel may be made by mixing 9 parts enamel, W.A.C. Specification No. 5860 to 1 part Toluol, W.A.C. Specification No. 5865. Refer to section in Appendix entitled SHOP MATERIALS.

Apply a second coat of Blue-Gray enamel and follow the procedure described above.

The enamel after being baked shall be hard enough to resist the action of gasoline at room temperature and lubricating oil at 325 deg. F. (163 deg. C.).

For complete removal of the old Blue-Gray enamel on sections which have not been subjected to cleaning solutions use steel wool for an abrasive and a mixture consisting of 50% each acetone and Toluol W.A.C. Specification No. 5865. The parts may be sandblasted if such equipment is available.

**BLACK ENAMEL** This finish is used on cylinder air deflectors, intake pipes, push rod housings and rocker box covers.

As previously described in BLUE-GRAY ENAMEL all parts must be thoroughly cleaned before painting.

Apply a light coat of Zinc Chromate primer and bake at 250 deg. F. (120 deg. C.) for 1½ hours.

Apply the first coat of Black Baking Enamel,

place in a flameless oven at 250 deg. F. (120 deg. C.) and bake for 1½ hours.

Apply a second coat of Black Enamel and proceed as above.

Black Baking Enamel may be made by mixing 9 parts enamel, W.A.C. Specification No. 5856 to 1 part Toluol W.A.C. Specification No. 5865. Refer to the section in Appendix entitled SHOP MATERIALS.

The enamel after being baked shall be hard enough to resist the action of gasoline at room temperature and lubricating oil at 325 deg. F. (163 deg. C.).

**FINISHING CYLINDERS** Before painting a cylinder, the surface must be carefully prepared.

The condition of the surface governs to a great extent the preparations necessary to obtain a satisfactory finish. The appearance of the completed work is also dependent upon the equipment available and the degree of finish required by the operator concerned.

Sandblasting effectively removes the old enamel, rusted or corroded areas, and roughens the surface of the metal to provide a good bonding surface for the enamel.

Some engines have the cylinders metalized as a corrosion prevention and are enameled over the metalizing. The old paint may be removed from cylinders that have been metalized and then painted, without disturbing the metalized coating, if the sandblasting operation is carefully controlled.

If sandblasting equipment is not available, burned or chipped enamel may be cleaned and smoothed with sandpaper. The cylinder should be free from grease or oil prior to re-enameling.

After the surfaces have been prepared and cleaned the cylinder should be made ready for spraying as follows:

Install dummy plates on the exhaust flanges and on the intake flanges.

Install plugs in both push rod housing connections and cover the outside surfaces with masking tape.

Install dummy plugs in the spark plug inserts, rocker bolt holes and cylinder mounting flange holes. An old set of spark plugs with washers may be used to protect the threads and face of the spark plug insert. Plugs for rocker bolt and cylinder mounting flange holes should be provided that will protect the spherical seats at these locations.

Insert screws in cylinder head and inter-cylinder baffle attaching bushings.

Install a sleeve on the outer surface of the cylinder barrel skirt below the mounting flange to protect this surface as well as the underside of the flange.

Install covers on the rocker boxes. Figure 159 shows a cylinder prepared for enameling.

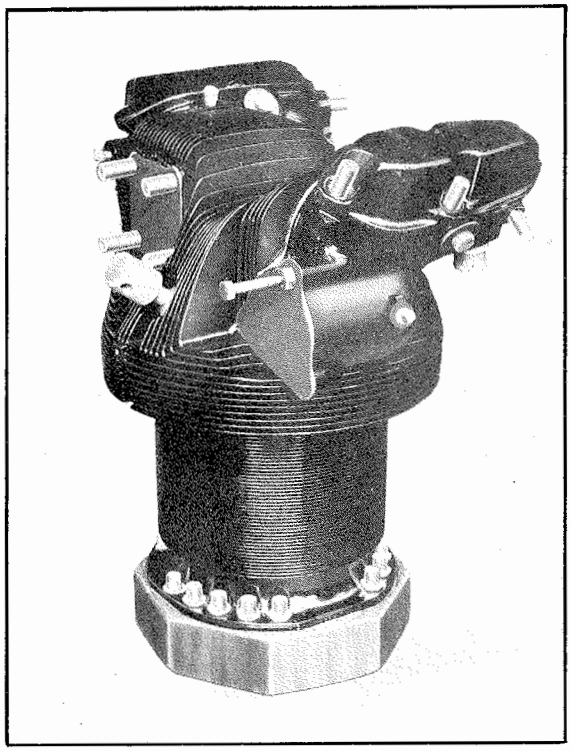


**Fig. 159. Method of Masking a Cylinder for Enameling**

Apply a priming coat of Hilo No. 938. Remove all plugs. Place the cylinder in an oven heated to 400 deg. F. (205 deg. C.) and bake for 2½ hours. Remove the cylinder and allow it to cool. Refer to section in Appendix entitled SHOP MATERIALS.

Reinstall the plugs, apply a coat of Hilo

No. 934 black finishing enamel, remove the plugs, place the cylinder in an oven and bake for 2½ hours at 440 deg. F. (205 deg. C.). Remove the cylinder and allow it to cool. Refer to section in Appendix entitled SHOP MATERIALS.

The finish may be improved by applying two coats of enamel.

## STUD REPLACEMENT

If any stud replacements are necessary, make these replacements in accordance with the instructions in this section.

**REMOVING ¼—20 STUDS** If the stud requiring replacement is not broken, it may be removed by using stud remover (Tool No. 801490).

If the stud requiring replacement is broken, it will be necessary to drill the stud using drills of successively larger diameter, and then remove the remaining shell using a removing tool. If the fracture of the broken stud is jagged, true up the end of the stud so that the starting drill may be accurately centered. If the stud is broken below the mounting surface, true up the end of the stud using a double-fluted end cutter slightly smaller in diameter than the root diameter of the stud. Use a suitable drill jig with a drill bushing when performing this operation, centering the drill bushing over the stud hole and clamping the jig in this position to avoid damaging the stud hole threads.

Drill the broken stud, using the drill jig clamped centrally over the stud hole. Using drill No. 41, 30, and 19 with proper drill bushings, successively drill holes of .096 inch (2.43 mm), .1285 inch (3.26 mm), and .166 inch (4.21 mm) diameter, respectively, in the stud. If the stud hole is tapped blind, take care to insure that the drill does not bottom in the stud hole.

Insert a square stud removing tool, measuring .175 inch (4.44 mm) across diagonal corners, into the drilled hole in the stud and screw out the remaining shell.

**INSTALLING ¼—20 STUDS** Clean up the stud hole threads using a ¼—20 standard size tap. CAUTION: Carefully inspect all taps before using in an engine part, since rough edges or burrs on the tap may cause the tap to cut an oversize hole. All taps should be tried in a test block made of the same material as that in which the tap is to be used. The tap being tested should not free itself enough to shake in the tapped hole. If such shaking is possible, that is an indication that the tap is not free of burrs. Remove burrs if necessary.

Select a ¼—20 standard size stud. If the stud is to be installed in a blind hole, coat the threads with engine lubricating oil. If the stud is to be installed in a hole that has been drilled through, apply a thin coating of Glyptal to the bottom threads in the stud hole, and lightly coat all except the first or leading thread on the new stud with AN-9516. (Refer to the section in Appendix entitled SHOP MATERIALS).

Screw the stud into the stud hole using stud driver (Tool No. 80402 for studs having a ¼—28 nut end thread) and torque wrench (Tool No. 84922). (Refer to the Table of Limits for the proper torque to be used in driving studs). If, after applying the proper torque, the nut end of the stud is not at the proper height above the mounting surface, remove the stud. Retap the stud hole slightly deeper using the standard size tap and reinstall the standard size stud if the stud height is too great. Retap the stud hole using an oversize tap and install a new stud having the corresponding oversize if the stud height is too low.

Studs are supplied in the three following oversizes: .003 inch, .007 inch, and .012 inch. Oversize ¼—20 taps may be procured for these oversize studs under Tool No. 84848, 84231, and 84232 respectively.

**REMOVING 5/16—18 STUDS** Follow the same procedure for removing 5/16—18 studs as previously described for ¼—20 studs. Use drill No. 38, 19, and 3 successively with proper drill bushings to drill holes of .1015 inch (2.57 mm), .166 inch (4.21 mm), and .213 inch (5.41 mm) diameter, respec-

tively, in broken studs. Use a square removing tool measuring .223 inch (5.66 mm) across diagonal corners to remove the remaining shell.

**INSTALLING 5/16—18 STUDS** Clean up the stud hole threads using a 5/16—18 standard size tap.

Follow the same procedure for installing 5/16—18 studs as previously described for 1/4—20 studs. Use stud driver (Tool No. 80402 for studs having a 1/4-28 nut end thread, and Tool No. 80403 for studs having a 5/16—24 nut end thread). (Refer to the Table of Limits for the proper torque value to be used).

Oversize 5/16—18 tap for .003 inch, .007 inch, and .012 inch oversize studs may be procured under Tool No. 84849, 84233, and 84234, respectively.

**REMOVING 3/8-16 STUDS** Follow the same procedure for removing 3/8—16 studs as previously described for 1/4—20 studs. Use drill No. 38 and 19, followed by a standard 17/64 inch diameter drill, with proper drill bushings, to drill holes of .1015 inch (2.57 mm), .166 inch (4.21 mm), and .2656 inch (6.74 mm) diameter, respectively, in broken studs. Use a square removing tool measuring .273 inch (.693 mm) across diagonal corners to remove the remaining shell.

**INSTALLING 3/8-16 STUDS** Clean up the stud hole threads using a 3/8—16 standard size tap.

Follow the same procedure for installing 3/8—16 studs as previously described for 1/4—20 studs. Use stud driver (Tool No. 80403 for studs having a 5/16—24 nut end thread, and Tool No. 80404 for studs having a 3/8—24 nut end thread). (Refer to the Table of Limits for the proper torque value to be used).

Oversize 3/8—16 taps for .003 inch, .007 inch, and .012 inch oversize studs may be procured under Tool No. 84850, 84505, and 84506, respectively.

**REMOVING 7/16-14 STUDS** Follow the same procedure for removing 7/16—14 studs as previously described for 1/4—20 studs. Use 1/8 inch, 1/4 inch, and 19/64 inch diameter drills successively with proper drill bushings to drill holes of .125 inch (3.17 mm), .250 inch (6.35 mm), and .297 inch (7.54 mm) diameter, respectively, in broken studs. Use a square removing tool measuring .317 inch (8.05 mm) across diagonal corners to remove the remaining shell.

**INSTALLING 7/16-14 STUDS** Clean up the stud hole threads using a 7/16—14 standard size tap.

Follow the same procedure for installing 7/16—14 studs as previously described for 1/4—20 studs. Use stud driver (Tool No. 80404 for studs having a 3/8—24 nut end thread). (Refer to the Table of Limits for the proper torque value to be used).

Oversize 7/16—14 taps for .003 inch, .007 inch, and .012 inch oversize studs may be procured under Tool No. 84836, 83089, and 83581, respectively.

Information regarding the procurement of drill jigs for special applications may be obtained from the Service Division of the Wright Aeronautical Corporation upon request.

# ANTIFRICTION BEARINGS

No repair should ever be attempted on an antifriction bearing except stoning the outside diameter of the outer race or the inside diameter of the inner race or the ends of either race to remove slight nicks or scoring. Care should be exercised to insure that the limits and proper fits of the bearing are not exceeded. If inspection of an antifriction bearing indicates the presence of any damage other than scratching or scoring of these surfaces, replace the bearing with a new part.

When antifriction bearings are received from the manufacturer, do not break the box seal or unpack each bearing in order to check the packing slip. Bearing numbers are printed plainly on the outside of the box. Above all, do not break the box seals before delivering bearings to the mechanic who will install them. Store bearings in a cool, dry place until ready for use.

Be sure that every box is sealed. In case the seal has been broken, remove the top lid and see if the waxed paper in which the bearing is wrapped is broken or shows signs of having been opened. Determine if the seal was broken due to rough handling in transit or in unpacking. If it appears that the seal was broken due to carelessness, reseal with a piece of gummed tape, if it is certain no dust or dirt could possibly have reached the bearing. If the bearing box is badly mutilated and the waxed paper punctured or torn, the bearing should not be put into service until it has been carefully inspected to determine whether dirt could have gotten into the grease in which the bearing is packed.

It is not necessary to wash the lubricant from new bearings providing the package has not been opened. The bearing manufacturer uses a high grade nonacid lubricant free from all chemicals and impurities that might cause corrosion. In every case where the package has been opened and dirt and dust has had an opportunity of lodging in the bearing, it will be necessary to clean the bearing as described in the chapter entitled CLEANING OF ENGINE PARTS, under the subtitle ANTI-FRICTION BEARINGS.

The first rule in handling bearings is clean hands and clean tools. Keep plenty of clean rags available and use them often. Do not use waste as the lint and short strands adhere readily to oiled surfaces. Keep hands wiped dry.

A very important protective measure is to keep the assembly benches where antifriction bearings are handled as clean as possible. It is good practice to place a clean sheet of paper on the bench on which the bearings can be placed just prior to their installation in the engine. This eliminiates the possibility of dirt and metal chips from the bench sticking to the oiled surface and being carried into the engine.

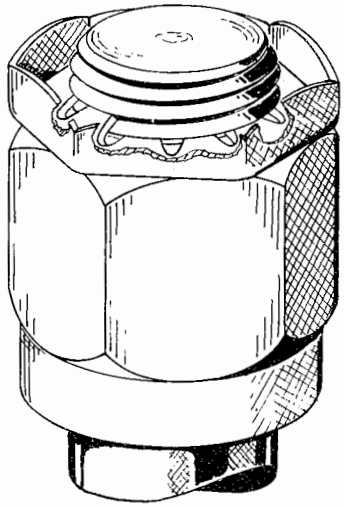
# GENERAL ASSEMBLY PROCEDURE

The successful operation of the engine is dependent upon the attention given to every detail, not only during the inspection and repair, but also at the time the final assembly is accomplished. It should be constantly borne in mind that neglect or carelessness in the manner in which the simplest of shop operations is performed may result in failure of the engine. The following information is offered as a means of aiding operators in establishing a shop procedure which will result in greater safety and a more uniform and higher type of workmanship. Certain of this information may be elementary to many operators and their shop personnel, however, it is repeated herein in the interest of uniformity.

The following engine parts should not be used a second time: gaskets, packing, lock wire, cotter pins, palnuts, circlets, piston pin retainers, piston rings, oil seal rings, push rod housing hoses, generator and magneto drive oil seal diaphrams and ignition wire cable.

Install palnuts as shown in figure 160.

Great care should be taken to prevent dirt, dust, cotter pins, lock wire, nuts, washers, and



TIGHTEN NUT TO BE LOCKED TO DESIRED TENSION — SPIN PALNUT ONTO SCREW UNTIL IT TOUCHES NUT. LOCK PALNUT WITH A WRENCH BY TIGHTENING ¼ TO ⅓ OF A TURN.

**Fig. 160. Method of Installing Palnuts**

any other small parts from falling inside the engine. It is advisable to keep all spark plug holes, intake pipe openings, carburetor inlet opening, and all accessory drive openings well covered until the respective part is installed in place. Suitable metal breather type plugs to fit the spark plug holes, metal plates to snap in place in the intake pipe openings, and a metal plate for the carburetor inlet opening can be made by the operator.

If the disassembled engine is to stand for any length of time before assembly can be completed, all steel parts should be covered with oil to prevent corrosion.

Completely finish each step in the process of assembling as the work progresses. Do not leave a bolt loose or nut unsafetied, with the idea of coming back to it later. Detail parts, sub-assemblies or partially assembled engines should always be properly covered when not being worked on.

Never slack off a nut in order to line up a slot in the nut with the cotterpin hole in the bolt or stud. Replace it with another nut if it cannot be tightened to line up properly within the required torque limits.

Before being assembled in the engine, all parts should be thoroughly cleaned and free from grit or dust. Wipe them with a clean, dry rag, which is free from lint. Never use cotton waste or tattered rags.

Remember that the engine will operate for a short period before the oil pump will start to furnish the regular supply of oil. Coat all bearing surfaces, therefore, with a good supply of engine lubricating oil before assembling. Nuts and parts which are a drive fit should likewise be oiled.

It is recommended that engine oil be applied freely to the pistons and rings just prior to their assembly in the engine, whether they are new or used pistons. This will improve piston ring operation and reduce wear on the piston rings during the first few hours of operation.

A torque indicating wrench should be used when tightening nuts during engine assembly and the tightening torque values listed in the applicable Table of Limits should be adhered to.

Observe the following precautions when using a torque wrench:

1. Make certain that no part of the wrench binds on any part of the engine.
2. Install the wrench in such a position that the nut or cap screw may be pulled up to the required torque without interruption.
3. The torque load should be applied until the nut or cap screw has ceased to turn. This may require several seconds from the time that the indicator reaches the required torque value.

Steel cotter pins which conform to the requirements outlined in the section in the Appendix entitled SHOP MATERIALS must be used in every case in order to insure proper safety. Brass cotter pins should never be used.

Select cotter pins to fit tight in the hole. Always install the head or loop end of the cotter pin to fit in the slot of the nut, not across or outside the slot, and bend the ends, one up and back over the bolt or stud end, and the other down and flat against the hexagon flat.

When using lock wire select a size which will fit the hole fairly tight and twist uniformly with pliers to obtain tight loops at each end. The wire should be tight so that vibration will not cause the wire to chafe and break.

# CRANKCASE FRONT SECTION

Refer to the sections entitled GENERAL REPAIR PROCEDURE, STUD REPLACEMENT, and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

Reinstall all oil passage plugs in the crankcase front section.

**PROPELLER GOVERNOR DRIVE** If replacement of the governor drive gear shaft bushing is found to be necessary, remove the used bushing and install a new bushing using the set of tools designed for this purpose (Tool No. 800998). Instruc-

tions for performing this replacement are included on blueprint No. 83748 which is provided with this set of tools.

Assemble the governor drive gear to the governor drive gear shaft, using six attaching screws. Insure that the proper cap screws are used. The proper screws for use in this location are ¼ inch (6.35 mm) long, measured from the underside of the screw head to the end of the thread. Secure the cap screws with lock wire.

Lubricate the propeller governor drive gear shaft and bushing, and install the shaft in the bushing from the interior of the crankcase front section. Install a new locking circlet on the anti-gear end of the shaft.

Install a new gasket and the governor substituting cover on the crankcase front section, and secure with flat washers, plain nuts, and palnuts.

**THRUST BEARING —.666 (3:2) REDUCTION GEAR** For instructions regarding the repair and handling of the thrust bearing, refer to the section entitled ANTIFRICTION BEARINGS, included at the beginning of this chapter.

In engines provided with a .666 (3:2) reduction gear, proceed with the assembly of the crankcase front section as follows, after installation of the propeller governor drive: Place the crankcase front section on a bench, front end down. Install the thrust bearing in the thrust bearing retainer, insuring that the side of the bearing marked PROPELLER END is towards the front of the retainer. If the thrust bearing incorporates a split inner race, it will be necessary to install only the outer race, cage and balls, and the rear half of the inner race at this time. Tap the thrust bearing outer race lightly to insure that it is contacting the front lip of the retainer.

Determine the thrust bearing side clearance as follows: Place two feeler gages of equal and known thickness on the antipropeller side of the thrust bearing outer race, 180 deg. apart. Install the stationary reduction gear, tapping it firmly in place against the shims. Measure the clearance between the stationary reduction gear and the crankcase front section. The difference between the measured clearance and the shim thickness is equal to the thrust bearing side clearance. (Refer to the applicable Table of Limits.) Remove the stationary reduction gear and shims.

**STATIONARY REDUCTION GEAR —.666 (3:2) REDUCTION GEAR** Stoning the faces of the stationary reduction gear teeth is not permitted under any circumstances.

If the inside diameter of the stationary reduction gear is worn by the thrust bearing spacer oil seal rings, grind the inside diameter of the gear oversize. To do this, set up the gear in an internal grinding machine, or in a lathe with a tool post grinder, and grind the bore to either .005 inch (0.127 mm) or .010 inch (0.254 mm) oversize diameter, as required. After grinding, check to make sure that the inside diameter of the gear is concentric with the mounting flange and the thrust bearing outer race pilot, using a dial indicator. Break sharp edges at the ends of the bore to 1/64 inch (0.397 mm) radius after grinding. NOTE: Oversize thrust bearing spacer oil seal rings must be used in every case with a stationary reduction gear which has been ground oversize on the inside diameter. Use oversize rings corresponding to the gear inside diameter oversize.

Install the stationary reduction gear in position in the crankcase front section and install the pinion guard ring in position on the gear. Secure the gear and ring with flat washers, castellated nuts, and lock wire on the two studs in the interior of the crankcase front section. Install the eight stationary reduction gear attaching bolts from the interior of the front section. Insure that the head of each bolt is properly seated against the flange of the stationary reduction gear, and snap the retaining circlets in the groove in the threaded end of the bolts.

**THRUST BEARING SPACER—.666 (3:2) REDUCTION GEAR** Fit new oil seal rings in the thrust bearing spacer, insuring that the proper ring side clearance and gap are obtained. (Refer to the applicable Table of Limits.)

Lubricate the thrust bearing spacer and ring assembly and the inside diameter of the stationary reduction gear, and install the spacer

and ring assembly in the gear. Exercise care to insure that the rings are not damaged when installing the spacer in the gear. The end of the spacer which is provided with a lip on the inside diameter must be toward the front of the gear.

Turn the crankcase front section over on the bench so that the front end is up. If the thrust bearing incorporates a split inner race, install the front half of the inner race at this time. CAUTION: Check to insure that all parts of the thrust bearing assembly bear the same serial number, if the bearing is of the split inner race type. Failure of the bearing may result from the use of mismatched halves of the split inner race, outer race, and retainer and balls.

**CRANKCASE FRONT SECTION FLANGE AND SPACER—.666 (3:2) REDUCTION GEAR** If the inside diameter of the crankcase front section flange is worn by the thrust nut oil seal rings, grind the inside diameter of the flange oversize. To do this, set up the flange in an internal grinding machine, or in a lathe with a tool post grinder, and grind the bore to either .005 inch (0.127 mm) or .010 inch (0.254 mm) oversize diameter, as required. After grinding, check to insure that the inside diameter of the flange is concentric with the mounting flange and with the front section bore pilot, using a dial indicator. Break sharp edges at the end of the bore to 1/64 inch (0.397 mm) radius after grinding. NOTE: Oversize thrust nut oil seal rings must be used in every case with a front section flange which has been ground oversize on the inside diameter. Use oversize rings corresponding to the flange inside diameter oversize.

If the thrust bearing is of the split inner race type, install the front half of the inner race at this time, before assembling of the front section spacer and flange.

Install a new gasket, the front section flange, and the aluminum spacer in position on the crankcase front section, and secure with ten flat washers and castellated nuts, using a torque indicating wrench. (Refer to the applicable Table of Limits for the proper tightening torque to be used in tightening the nuts.) Lockwire the nuts in pairs.

Turn the crankcase front section over on the bench front end down, locating the front section centrally over a hole five inches (125 mm) in diameter cut in the bench. This hole will accommodate the propeller shaft when installed. If the thrust bearing is of the split inner race type, locate assembly block (Tool No. 801560) over the hole in the bench, and invert the crankcase front section over the block. The block supports the front section on the thrust bearing inner race, which is necessary during installation of the propeller shaft when this type of bearing is used.

**PROPELLER SHAFT FRONT BUSHING—.666 (3:2) REDUCTION GEAR** If replacement of the propeller shaft front bushing is found to be necessary, perform this replacement in accordance with the following instructions: Clamp the propeller shaft rear end to a lathe face plate. Screw the steady rest bushing (Tool No. 83995) on the propeller hub nut threads on the propeller shaft, and support the front end of the shaft by means of a steady rest over the bushing. Indicate the surface forward of the propeller shaft splines, and the shoulder behind the thrust bearing journal, to run true within .002 inch (0.051 mm) full indicator reading. Bore out the flange of the bushing to a diameter of $2\frac{13}{32}$ inches (61.12 mm) and to a depth of 1/4 inch (6.35 mm). Bore out the bushing to a diameter of 2.150 inches (54.61 mm), leaving a shell .005 inch (0.127 mm) thick remaining in the shaft. Remove the shaft from the lathe and pick out the bushing flange and the remaining shell. Remove the washer. CAUTION: Take care to insure that the propeller shaft sleeve is not damaged during this operation.

Remove sharp edges and smooth the bushing bore in the shaft. Check the inside diameter of the bushing bore and the outside diameter of the new bushing to insure that the proper tight fit will be obtained. (Refer to the applicable Table of Limits.)

Heat the propeller shaft in an oil bath at a temperature of 400 deg. F. (205 deg. C.) for twenty minutes. At the same time, install the new bushing on its pressing-in plug (Tool No. 84308), and chill these parts in a solution of denatured alcohol and dry ice for twenty minutes.

Place the propeller shaft, rear end down, on a fiber pad on an arbor press table to prevent scratching the shaft when pressing in the bushing. Install a new propeller shaft front bushing washer in position in the shaft. Press the new front bushing into the shaft using the plug (Tool No. 84308) until the bushing flange is bottomed on the washer. Remove the plug.

It is necessary to finish bore the propeller shaft bushings after installation in the shaft. This operation is accomplished in boring fixture (Tool No. 84617). Locating bushings (Tool No. 84618 and 84619) are used in this fixture in order to centralize the propeller shaft in the fixture. Install adapter (Tool No. 84621) and bushing (Tool No. 84618-1) in position in the fixture. Lock the bushing in position on the adapter using the three cap screws. Install bushing (Tool No. 84619) in position in the fixture and secure with the six cap screws. Install the propeller shaft, front end down, in the locating bushings in the fixture, and clamp by means of the clamping plate (Tool No. 84618-2), securing the clamping plate using the three nuts. Turn the bronze hand wheel to lock the propeller shaft in position. Bend down the hinged cover of the fixture (Tool No. 84617-3), and turn the two wing nuts to lock the cover in position. (See blueprint No. 84617, which is furnished with this tool, for a sketch of the propeller shaft and tools in position in the fixture.)

Boring bar (Tool No. 802052-1) and tool bit (Tool No. 802052-2) are used in finish boring the propeller shaft front bushing. Insert the tool bit in the boring bar. Gage (Tool No. 801101-1) is used in setting the tool bit. Attach the gage to the anvil of a micrometer. Determine the proper setting of the tool bit as follows: Measure and record the diameter of the crankshaft at the propeller shaft front bushing journal. Refer to the applicable Table of Limits for the proper clearance between the crankshaft and the propeller shaft front bushing, and record the minimum clearance. To one-half of the crankshaft diameter, add one-half of the desired clearance. Add to this the gage constant, which is stamped on the gage. The total of these three items is the dimension to which the tool bit should be set, measured to the cutting edge of the tool. Lock the tool bit in the boring bar by means of the set screw.

**EXAMPLE**

Diameter of Shaft .....1.978 inches (50.240 mm), one-half equals .989 inches (25.120 mm)
Desired Clearance .....0.0025 inches ( 0.63 mm), one-half equals .0013 inches ( 0.032 mm)
Gage Constant ..... .900 inches (22.860 mm)
Set Cutter to ..... 1.8903 inches (48.012 mm)

**CAUTION:** When setting the tool bit, do not drag the micrometer spindle heavily over the cutting edge of the tool, since this may damage the micrometer, dull the tool, or result in an improper setting. Use a light touch to insure that the finished bore will be of the correct diameter. Move the micrometer spindle away from the cutting edges of the tool, from the clearance angle toward the cutting tooth. Check the setting of the tool bit after locking.

Install slip bushing (Tool No. 84626) in the cover of the fixture, and install the boring bar in the slip bushing, resting the bar on a supporting pin. (See blueprint No. 84617). Place the fixture on a drill press bed plate. Install chuck (Tool No. 83921) in the drill press spindle, and locate the drill press spindle directly over the boring bar. Lower the spindle, attach the chuck to the boring bar, remove the supporting pin, and bore the bushing to size. Remove the propeller shaft from the fixture.

**PROPELLER SHAFT REAR BUSHING—.666 (3:2) REDUCTION GEAR**

If replacement of the propeller shaft rear bushing is found to be necessary, perform the replacement in accordance with the following instructions: Clamp the propeller shaft horizontally in a vise or other suitable holding fixture so that the propeller shaft rear bushing pin is pointed directly upward. Use soft metal strips over the

jaws of the vise to avoid damaging the propeller shaft.

Mark the center of the head of the pin, using a center punch. Using a standard 9/32 inch (7.144 mm) diameter drill, drill a hole .115 inch (2.92 mm) deep, to remove the head of the pin. Drill no deeper than is necessary to remove the pin head.

Drive out the pin. Install the propeller shaft in boring fixture (Tool No. 84617), used in connection with locating bushings (Tools No. 84618 and 84619), and adapter (Tool No. 84621), in the same manner as previously described for finish boring the propeller shaft front bushing. Bore out the propeller shaft rear bushing, using boring bar (Tool No. 802052-1) and tool bit (Tool No. 801101-2). Install the slip bushing (Tool No. 84626) on the boring bar. Set the stop collar on the bar to limit the travel of the cutter to avoid damaging the propeller shaft sleeve. Set the tool bit to the small diameter of the setting gage (Tool No. 801101-1), and lock it with the set screw. Install the bar in the fixture, permitting it to rest on a supporting pin. Install chuck (Tool No. 83921) in the drill press spindle, lower the spindle and attach the chuck to the boring bar, remove the supporting pin, and bore out the bushing. Make a second cut in the same manner after resetting the tool bit to the large diameter of the gage (Tool No. 801101-1). Remove the shaft from the fixture.

Pick out the remaining shell of the bushing. Remove sharp edges and smooth the bushing bore in the shaft. Check the inside diameter of the bushing bore and the outside diameter of the new bushing to insure that the proper fit will be obtained. (Refer to the applicable Table of Limits).

Heat the propeller shaft in an oil bath at a temperature of 400 deg. F. (205 deg. C.) for twenty minutes. Install the new bushing on its pressing-in-plug (Tool No. 801916-3) after drawing pencil lines lengthwise on the bushing and bushing bore in the shaft through the oil holes. Chill the bushing in a solution of denatured alcohol and dry ice for 20 minutes.

Hold the propeller shaft, front end down, on a fiber pad on an arbor press table. Press the new rear bushing into the shaft using the plug (Tool No. 801916-3) until the bushing is bottomed on the rear end of the propeller shaft sleeve. Make sure that the pencil marks on the bushing and shaft are aligned during this operation to insure proper alignment of the oil holes in the bushing and shaft. Remove the plug.

Drill a 15/64 inch (5.953 mm) diameter hole through one wall of the new bushing at the lock pin hole in the shaft, using a standard 15/64 inch (5.953 mm) diameter drill. Ream this hole to a diameter of .2485 to .2495 inch (6.312 to 6.337 mm), and check it using plug gage (Tool No. 83933). Drive in a new lock pin.

Finish bore the propeller shaft rear bushing in the same manner as previously described for the front bushing. Use tool bit (Tool No. 801103-3), and gage (Tool No. 801101-1) when finish boring the rear bushing.

**PROPELLER SHAFT PINION BUSHINGS —.666 (3:2) REDUCTION GEAR** When replacement of any of the reduction gear pinion bushings is necessary, perform the replacement in accordance with the following instructions: Clamp the propeller shaft in the bench assembly fixture, (Tool. No. 803529) locating the pinion arm and bushing requiring replacement in an upward position. Mark the center of the head of the lock pin with a center punch. To remove the head of the pin, drill it with a 9/32 inch (7.144 mm) drill, to a depth of 3/32 inch (2.381 mm). It may be necessary to use a 5/16 inch (7.938 mm) drill to remove the peened over metal from the edge of the lock pin hole in the shaft in order to pick out the head of the pin. The pin may then be driven out.

Install the propeller shaft in the boring fixture (Tool No. 84617), which is used in conjunction with the locating bushings (Tools No. 84618-1 and 84619) and adapter (Tool No. 84621). Use the aligning plug (Tool No. 84618-3) to align the pinion bushing and the pilot bushing in the fixture. Tighten the hand wheel to lock the propeller shaft in this position and remove the aligning plug.

Bore out the pinion bushing in two cuts, using the boring bar (Tool No. 802059), tool bit (Tool No. 84621-6), and chuck (Tool No. 83921). Set the tool bit for the first and second cuts using the small and large diameters, respectively, of the setting gage (Tool No. 84621-5). Remove the shaft from the fixture and pick out the remaining shell of the bushing.

Smooth the bushing bore, and measure the outside diameter of the new bushing and the

inside diameter of the bushing bore to insure that the correct fit will be obtained. (Refer to the applicable Table of Limits).

Install the bushing on the pressing-in bar of the pinion bushing installing and aligning tool (Tool No. 801914). Assemble the pressing-in bar and bushing to the pressure plate of the tool, inserting the spring-actuated locating pin in the lock pin hole of the bushing. Heat the propeller shaft, and chill the installing tool and bushing in the manner previously described for the installation of the front and rear propeller shaft bushings. Place the rest plate (Tool No. 801914-11) on an arbor press table, and hold the propeller shaft so that the pinion bore and the bore in the rest plate are aligned and the splined end of the shaft overhangs the edge of the table. Place the installing tool on the pinion arm with the guide end of the pressing-in bar entering the bushing bore. The installing tool is held in location on the pinion arm by the two pins. Press the tool and bushing into the shaft, being careful to retract the locating pin before it contacts the pinion arm. When the pressure plate contacts the rear face of the pinion arm the bushing will be installed to the correct depth. When the propeller shaft has cooled to room temperature, remove the installing tool and inspect the oil holes and the lock pin holes for correct alignment with the mating holes in the pinion arm.

Drive in a new lock pin, and peen metal from the edge of the lock pin hole in the propeller shaft over the lock pin head.

Finish bore the pinion bushing in the manner previously described for the propeller shaft front and rear bushings, using the boring bar (Tool No. 802059), tool bit (Tool No. 84621-6) and gage (Tool No. 84623-2).

The complete set of tools for replacing all bushings in .666 (3:2) reduction gear ratio propeller shafts may be procured under Tool No. 800526.

**PROPELLER SHAFT AND PINIONS —.666 (3:2) REDUCTION GEAR**

When the edge or face of a pinion gear tooth is slightly nicked or scratched it may be stoned lightly, but in no case should the contour of the tooth face be altered. Pinion gear teeth which are slightly galled or pitted, may be lapped when the necessary special equipment is available. If this special equipment is not available the complete set of pinion gears must be returned to the factory for reconditioning.

It is recommended that only those pinion gears which are found unserviceable be replaced. When replacing pinion gears in less than a full set, make up sets of similar dimensions within our service limits. Upon assembly of the pinion gears, it will be necessary to check the backlash of all the pinion gears. (Refer to the applicable Table of Limits).

Install the propeller shaft in the assembly fixture (Tool No. 803529) to facilitate assembly of the pinion gears.

Lubricate the pinion gear shafts with engine oil and install the pinions in the bushings. Lightly coat the threads of the pinion lock bolts with Lubriplate 130-A, and install them in the pinions. The lock bolts are provided with a left hand thread.

Engage the pinion locking tool (Tool No. 83308) with the teeth of any two adjacent pinion gears. Tighten both lock bolts, using the torque wrench (Tool No. 84922) and adapter (Tool No. 800562), to the recommended torque value. Install and tighten the remaining lock bolts in this same manner.

Measure the end clearance of all the pinions. Press each pinion back to its extreme rear position, and measure the clearance between the rear face of the pinion arm and the flange of the lock bolt. (Refer to the applicable Table of Limits).

Select cotter pins for locking the pinion bolts. Use the cotter pin bending tool (Tool No. 800375) to bend the cotter pin heads to an angle of 45°. Insert the pins in the bolts so that the heads lie flat within the recesses in the bolt heads. Spread the split ends tight within the bolts to insure against loosening during engine operation. Illustration figures 161 and 162 deleted in revised pages.

The thrust bearing inner race and the thrust bearing spacer are shrunk fit on the propeller shaft and they must be expanded before installing the propeller shaft. Use the thrust bearing heating iron (Tool No. 800310) to expand the thrust bearing inner race. Heat the iron for 20 minutes in an oil bath maintained at a temperature of 350 to 400 deg. F. (177 to 205 deg. C.). Place the crankcase front section front end down over a hole in the assembly bench that will accommodate the propeller shaft when it is in-

stalled. Place the heating iron in the bore of the thrust bearing spacer and thrust bearing. See figure 163. Cover the heating iron with a heavy

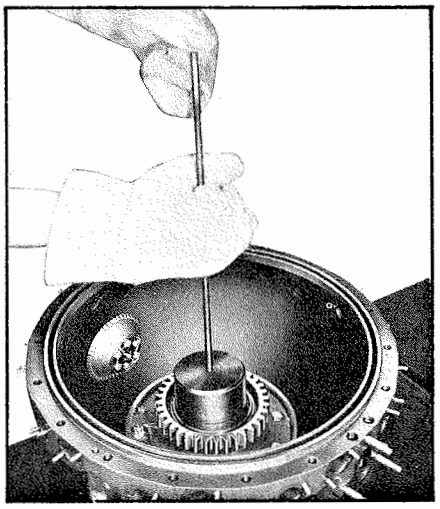


**Fig. 163. Heating Bore of Thrust Bearing Spacer and Thrust Bearing**

cloth to prevent loss of heat, and leave it in position for approximately ten minutes. Remove the heating iron and install the propeller shaft immediately, slightly rotating the shaft to mesh the pinions with the stationary reduction gear. When the thrust bearing incorporates a solid inner race, the thrust nut may be temporarily installed to hold the shaft in position before inverting the front section to a propeller end up position. When only the rear inner race of a split inner race bearing has been installed, it will be necessary to hold the propeller shaft in position with the assembly block. Install the assembly block in the propeller shaft, then slowly invert the crankcase front section to a nose up position. Install the ball bearing and retainer assembly in the outer race. To install the front half of a split inner race, heat the race for five minutes in an oil bath maintained at a temperature of 250 deg. F. (121 deg. C.). Install the front half of the inner race on the shaft insuring that the puller lip is toward the front end of the shaft. Tap the front inner race with a fiber mallet to insure that it is bottomed on the rear half of the inner race.

**THRUST NUT —.666 (3:2) REDUCTION GEAR** When it is necessary to remove galled areas on the front and rear faces of the thrust nut, these faces may be ground. Do not remove more than .005 inch (.127 mm) from either face, since exceeding this limit may remove the carburizing from these surfaces. Thrust nuts which have been reground should be identified so that this limit will not be exceeded at subsequent overhauls.

Fit new oil seal rings in the thrust nut, insuring that the correct ring side clearance and ring gap are obtained. (Refer to the applicable Table of Limits). Coat the propeller shaft thrust nut threads with Lubriplate No. 130A.

Lubricate the thrust nut and ring assembly with engine oil, and install the thrust nut on the propeller shaft. Exercise care to insure that the rings are not damaged as they enter the front section flange. Do not draw the thrust nut up to final tightness until final assembly of the engine.

**PROPELLER SHAFT FRONT AND REAR BUSHINGS —.5625 (16:9) RATIO REDUCTION GEAR** When replacement of the propeller shaft front and rear bushings is necessary, proceed in the following manner.

Plug all the oil holes and oil channels in the propeller shaft with beeswax or paraffin to prevent foreign particles from entering the oil passages.

Install the propeller shaft in the fixture (Tool No. 801100), using the adapter, (Tool No. 801102) and plate (Tool No. 84628-1) to secure the shaft pinion carrier flange. Use the bushing (Tool No. 84619) to support the front end of the shaft. Close and fasten the fixture cover. Assemble and install the boring bar (Tool No. 802052-1), boring bar stop collar (Tool No. 802052-3), boring fixture bushing, (Tool No. 84626) and tool bit (Tool No. 802358), supporting the weight of the tool by a length of drill rod inserted through the stop pin hole in the boring bar. Set the stop collar to prevent cutting into the steel propeller shaft sleeve forward of the bushing. Set the tool bit to bore the bushing to a diameter of 2.756 to 2.766 inches (7.000 to 7.026 cm). Install the fixture and shaft on a drill press table; center the fixture under the drill press spindle and assemble the boring bar assembly to the spindle, using a No. 3 chuck. Clamp the fixture to the table, remove the boring bar stop pin and make the first cut. Reset the tool bit to obtain a diameter of 2.979 inches (7.567 cm) and make the second cut. Pick out the remaining shell and drive the remainder of the bushing lock pin below the surface of the bushing bore. Mark the propeller shaft flange bolt hole opposite

the lock pin and remove the shaft from the fixture. Do not disassemble the fixture.

To remove the front bushing, clamp the fixture (Tool No. 800272) to the face plate of a lathe, and indicate it to run true within .002 inch (.051 mm). Fasten the rear flange of the propeller shaft to the fixture, using four plate screws and washers. Thread the front end supporting bushing on the propeller shaft nut threads, and support the bushing in a steady rest. Indicate the forward end of the shaft to run true within .001 inch (.0254 mm) full indicator reading. Set the stop collar on the boring bar assembly to prevent boring into the propeller shaft sleeve. Bore the front bushing to a maximum diameter of 2.140 inches (5.436 cm) and pick out the remaining shell. Remove the propeller shaft from the fixture and smooth both the front and rear bushing bores.

To install the front propeller shaft bushing, measure the outside diameter of the bushing and the inside diameter of the front bushing bore to insure that the correct fit is obtained. (Refer to the applicable Table of Limits). Install the bushing on the front bushing installing plug (Tool No. 84308) and immerse the bushing in a solution of dry ice and alcohol, or dry ice and gasoline, for 20 minutes. Heat the propeller shaft for twenty minutes in a flameless oven or oil bath maintained at a temperature of 401 deg. F. (205 deg. C.). Install the base, (Tool No. 84309) in the propeller shaft rear bushing bore, and place the shaft and base on an arbor press table. Install the front bushing washer on the shoulder forward of the steel sleeve in the shaft. Press in the bushing until it bottoms on the steel washer, and maintain the pressure until the bushing and shaft approach room temperature. Remove the installing tool and base.

To install the rear bushing in the shaft, assemble the bushing on the rear bushing installing and aligning tool (Tool No. 803168-1) so that the plunger engages a bushing oil hole. Chill the tool and bushing and heat the shaft in the manner described for the front bushing installation. Support the shaft on an arbor press table, placing a block of wood between the shaft and the table. Place the guide end of the installing tool in the bushing bore, and install the locating pin (Tool No. 803168-5) in the propeller shaft rear bushing oil hole. Depress the pin, engaging it with the locating slot in the installing tool. Press in the bushing until the installing tool bottoms on the rear face of the flange. Maintain the pressure until the shaft and bushing approach room temperature. Remove the installing plug, and remove the shaft from the press table.

To drill a new hole for the propeller shaft rear bushing lock pin, refill all oil holes and channels in the shaft with paraffin or beeswax to exclude chips from these passages. Install the shaft in the drill press fixture, and tighten the attaching screws. Install the lockpin drill locating fixture (Tool No. 803375) in the rear bushing and engage the jig locating pin in a flange bolt hole other than the one previously marked when the bushing was removed. Expand the jig in the rear bushing by tightening the cap screw, and install the drill bushing (Tool No. 803375-9). Use a $^{11}/_{64}$ inch (4.366 mm) drill to drill to a depth of 1.646 to 1.666 inches (4.181 to 4.232 cm). Replace the jig drill bushing with the jig reamer bushing (Tool No. 803375-10). Use the reamer (Tool No. 800154) to finish ream the drilled hole. Check the reamed hole with the plug gage (Tool No. 800194). Remove the reamer bushing and install the jig driver bushing. Drive in the new lock pin, using the pin driver (Tool No. 800376), until the shoulder of the driver contacts the face of the jig bushing. Remove the jig assembly from the propeller shaft.

Finish bore the front and rear bushings. Use the same fixture, boring bar assembly and chuck that were used to remove the old bushings. Finish bore the front and rear bushings using tool bits (Tools No. 802052-2 and 802368) respectively. Set the tool bits to obtain finished diameters that will give the correct clearances between the bushings and the crankshaft front extension bearing journals. (Refer to the applicable Table of Limits). Set the stop collar to prevent cutting the propeller shaft sleeve. Remove the stop pin, finish bore the bushings and check the bushing inside diameters.

Bore the taper in the rear of the bushing using the same boring bar assembly. Taper boring tool bit (Tool No. 800187) replaces the tool bits, (Tools No. 802052-2 and 802368). Insert the boring bar assembly into the fixture, and support it by inserting the stop pin in the boring bar. Set the tool bit to obtain a diameter of 2.627 to 2.629 inches (6.673 to 6.678 cm). The top of the tool bit should be aligned with the bottom of the 30 deg. chamfer in the rear bushing. Set the

boring bar stop collar. Remove the stop pin, and taper bore the bushing to an angle of 14 to 22 minutes, and to a depth of .330 to .460 inch (8.382 to 11.684 mm). Remove the boring bar assembly, and remove the shaft from the fixture. Break all sharp edges in both bushings. Dewax the oil passages by heating the shaft to 275 deg. F. (135 deg. C.) for 20 minutes. Flush the passages with kerosene heated to a maximum temperature of 120 deg. F. (49 deg. C.) under a pressure of approximately 20 lb. per sq. in. (1.407 kg. per sq. cm). Dry the passages with compressed air, and slush them with the corrosion preventive compound, Aeronautical Material Specification No. 3702.

The complete set of tools for replacing the propeller shaft front and rear bushings in .5625 (16:9) reduction gear ratio propeller shafts may be procured under Tool No. 800526 and Tool No. 801704. The tools included in this set of tools, (Tool No. 800526) are necessary for replacing bushings in both .5625 (16:9) and .666 (3:2) reduction gear ratio propeller shafts. The additional tools required for replacement of the bushings in .5625 (16:9) propeller shafts are included in the set of tools (Tool No. 801704).

This section describes the replacement of front and rear bushings in .5625 (16:9) propeller shafts using an improved boring fixture (Tool No. 801100) and an improved rear bushing installing tool (Tool No. 803168). This method improves upon, but does not supplant, the method previously described, which incorporates the use of the boring fixture (Tool No. 84617) and the rear bushing installing tool (Tool No. 801916), which are included in the tool group (Tool No. 800526).

**PROPELLER SHAFT AND PINIONS —.5625 (16:9) REDUCTION GEAR**

When the engine is equipped with a .5625 (16:9) ratio reduction gear, the crankcase front section assembly is built up on the propeller shaft. Proceed with the repair and assembly of the crankcase front section assembly in the following order. Install the propeller shaft in the assembly fixture (Tool No. 803529), tighten the fixture and install the propeller nut thread protecting cap. Coat the pinion carrier attaching bolts with Lubriplate No. 130-A. Locate the pinion carrier on the shaft, and ensure that the outside diameter of the propeller shaft flange does not interfere with the mating diameter of the pinion carrier. Install the attaching bolts and nuts, and tighten the nuts finger tight. Tighten a nut at the top of the carrier, and tighten a nut at the bottom located 180 degrees from the first. Tighten a nut at the horizontal center line and the next nut 180 degrees removed from the third. Tighten the remaining nuts in this manner, so that each nut tightened is diametrically opposed the preceding nut. Using the torque indicating wrench, tighten all the nuts to the recommended torque value. See figure 164. Refer to the applicable Table of Limits for the recommended torque value.

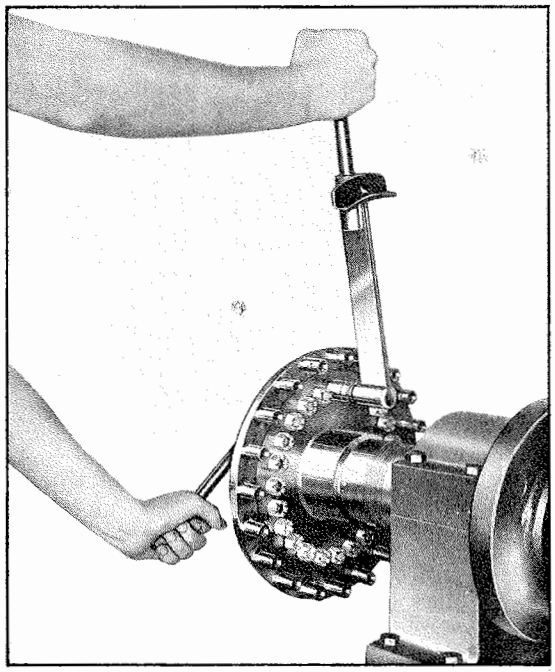


**Fig. 164. Tightening Pinion Carrier Attaching Nut (16:9)**

Replace only those reduction gear pinions and pinion bushings which are unserviceable. When replacing bushings in less than a complete set, make up sets of similar dimensions within the service limits. (Refer to applicable Table of Limits). When the pinion teeth are slightly nicked or scratched they may be stoned lightly. Do not alter the pinion tooth contour, as this will result in localized overloading. When the pinion teeth are slightly pitted or galled they may be lapped. The complete set must be returned to the factory for this operation unless all the special equipment and machinery is available for the operation.

The pinion carrier trunnions, pinion bushings and pinions used in .5625 (16:9) reduction gears

are no longer numbered for location. Lubricate the bushings with engine oil and insert them in their pinions so that the flanged end of the bushing is at the chamfered end of the inside diameter of the pinion. Install the pinions and bushings on their respective trunnions. Lightly coat the threads of the pinion lock bolts with Lubriplate 130-A. Install the lock bolts from the front of the trunnions, and install the nuts by hand. The lock bolts are provided with a left hand thread.

Engage the pinion locking tool (Tool No. 83507) in the slots in two bolt heads to prevent the bolts from turning, and tighten the nuts using a torque indicating wrench. See figure 165. Observe the torque value specified in the applicable

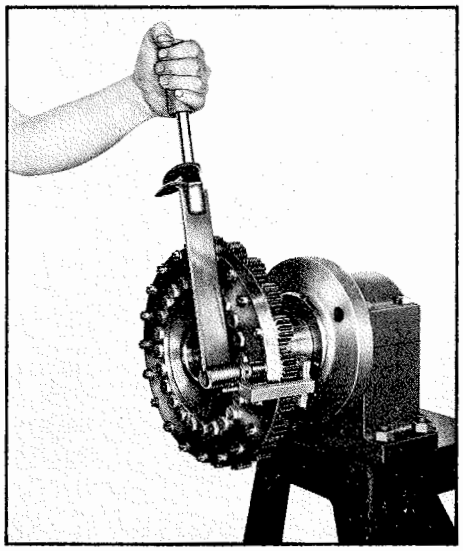


**Fig. 165. Tightening Pinion Lock Nut (16:9)**

Table of Limits. Tighten all pinion lock bolt nuts in this manner.

Check the end movement of the pinions. To do this, place the propeller shaft on a bench, rear end down. Measure the clearance between each pinion and its bushing, using a feeler gage. (Refer to the applicable Table of Limits). Cotter the lock bolt nuts securely.

**STATIONARY REDUCTION GEAR —.5625 (16:9) REDUCTION GEAR** Stoning the faces of the reduction gear teeth is not permitted under any circumstances.

Place the propeller shaft and pinion assembly on the assembly block. Install the stationary reduction gear in position on the propeller shaft, meshing the teeth on the gear with the pinion gear teeth. Place the pinion guard ring in position on the stationary reduction gear. Install two aligning studs (Tool No. 800695) in tapped holes in the stationary reduction gear. These studs will facilitate alignment of the stationary reduction gear and the crankcase front section upon assembly of these parts.

**STATIONARY REDUCTION GEAR SUPPORT— .5625 (16:9) REDUCTION GEAR** If the inside diameter of the stationary reduction gear support is worn by the thrust bearing spacer oil seal rings, grind the inside diameter of the support oversize in the same manner as previously described for the stationary reduction gear in .666 (3:2) reduction geared engines.

Before assembling the stationary reduction gear support on the propeller shaft, check the thrust bearing side clearance in the same manner as previously described for .666 (3:2) reduction geared engines.

**THRUST BEARING SPACER—.5625 (16:9) REDUCTION GEAR** Fit new oil seal rings in the thrust bearing spacer, insuring that the proper ring side clearance and gap are obtained. (Refer to the applicable Table of Limits.)

Lubricate the thrust bearing spacer and ring assembly and the inside diameter of the stationary reduction gear support with engine oil. Install the spacer and ring assembly in the support, exercising care to insure that the rings are not damaged. The end of the spacer which is provided with a lip on the inside diameter must be toward the front of the support.

Install the stationary reduction gear support and the thrust bearing spacer and ring assembly over the aligning studs in the stationary reduction gear. It may be necessary to tap the spacer into place on the propeller shaft, since the clearance between the spacer and the shaft is small. Take care that the position of the spacer relative to the support is not changed during the installation of these parts on the propeller shaft, since that might allow one of the rings to slip past the end of the support. Insure that the lip on the inside diameter of the spacer is bottomed on the shoulder on the propeller shaft, and that the stationary reduction gear support is bottomed on the gear.

**THRUST BEARING —.5625 (16:9) REDUCTION GEAR** For instructions regarding the repair and handling of the thrust bearing, refer to the section entitled ANTIFRICTION BEARINGS, included at the beginning of this chapter.

Heat the thrust bearing, or the halves of the inner race if the bearing is of the split inner race type, in an oil bath maintained at a temperature of 250 deg. F. (121 deg. C.) for five minutes. Install the bearing on the propeller shaft, insuring that the puller lip on the inner race is toward the front end of the shaft. If the bearing incorporates a split inner race, first install the rear half of the inner race, then the outer race, retainer and balls, and finally the front half of the inner race. Tap the front end of the inner race after installation to insure that it is bottomed on the thrust bearing spacer.

Lubricate the thrust bearing retainer in the crankcase front section with engine oil. Install the front section over the aligning studs in the stationary reduction gear. See figure 166.

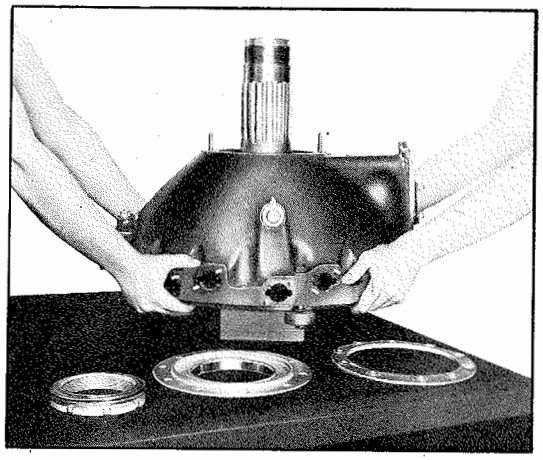


**Fig. 166. Installing Crankcase Front Section Over Propeller Shaft**

It may be necessary to wait until the thrust bearing has cooled before installing the front section, since the outer race of the bearing may have expanded sufficiently during heating to prevent its entering the retainer. Insure that the lip on the front end of the thrust bearing retainer is bottomed on the bearing outer race.

Install flat washers and cap screws in the counterbored holes in the front section. Use a torque indicating wrench to tighten these cap screws, and observe the proper torque value. (Refer to the applicable Table of Limits.) Remove the two aligning studs from the stationary reduction gear.

**CRANKCASE FRONT SECTION FLANGE AND SPACER—.5625 (16:9) REDUCTION GEAR** If grinding of the inside diameter of the crankcase front section flange is found to be necessary, do this in the same manner as previously described for .666 (3:2) reduction geared engines.

Install a new gasket, the front section flange, and aluminum spacer in position on the crankcase front section, and secure with ten flat washers and the special cap screws. Use a torque indicating wrench when tightening the cap screws. (Refer to the applicable Table of Limits for the proper torque to be used.) Lockwire the cap screws in pairs.

**THRUST NUT —.5625 (16:9) REDUCTION GEAR** Repair the thrust nut, if necessary, fit new rings, and install on the propeller shaft in the same manner as previously described for .666 (3:2) reduction geared engines.

**THRUST BEARING PROPELLER SHAFT AND TORQUEMETER PARTS—.666 (3:2) AND .5625 (16:9) REDUCTION GEARED ENGINES HAVING A TORQUEMETER** For the repair of all parts in the torquemeter crankcase front section, except the working parts of the torquemeter itself, refer to the foregoing text.

In engines provided with a torquemeter, the torque arm and support assembly must be installed in the crankcase front section before the beveled booster pump drive gear.

Assemble the torque arm and support assembly by installing the balls which hold these parts together. To do this, stand the support on a bench, sleeve end down. Hold the torque arm in position over the support so that the circular slots in the torque arm and support are aligned. Insert the balls, one by one, in the circular hole formed by the mating

slots. When all the balls are installed, turn the torque arm relative to the support so that the circular slots are misaligned.

Place the crankcase front section on a bench, front end down. Lubricate and install the thrust bearing front spacer and the thrust bearing in the retainer in the front section. Check the thrust bearing side clearance. (Refer to the applicable Table of Limits.)

Install the torque arm and support assembly in the front section, over the projecting end of the thrust bearing. To do this, first insert the end of the torque arm through the hole provided for it in the top of the front section. Then press the support in position on the bearing. Be careful not to scratch or otherwise damage any parts when installing this assembly. Turn the support on the bearing until the attaching cap screw holes are aligned with the holes in the crankcase front section. Lift the front section and invert it, holding the torque arm support in position by hand, and place the assembly, front end up, on a block underneath the support. The block should be high enough to raise the front section parting flange clear of the bench. Install two flat washers and cap screws in the counterbored holes in the front section. Use a torque indicating wrench to tighten these cap screws, and observe the proper torque value. (Refer to the applicable Table of Limits.)

Install a new crankcase front section flange gasket, the flange, and the aluminum spacer in position on the front section, and secure with ten flat washers and the special cap screws. Use a torque indicating wrench to tighten the cap screws. (Refer to the applicable Table of Limits for the proper torque value to be used.)

Assemble the beveled booster pump drive gear and shaft and install in the crankcase front section in the same manner as previously described for the governor drive gear and shaft in engines without a torquemeter.

Place the front section on the bench, front end down, and install the thrust bearing spacer and ring assembly in the torque arm support in the same manner as previously described for .666 (3:2) reduction geared engines without a torque indicator. Install the stationary reduction gear in the splines of the torque arm support. NOTE: The splines on the stationary reduction gear and the torque arm support are marked so that the gear may be reinstalled in its original position with relation to the support. Insure that the marked splines are lined up.

Install the propeller shaft and pinion assembly in the same manner as previously described for .666 (3:2) reduction geared engines without a torquemeter, after heating the thrust bearing inner race and spacer, using the heating iron. Install the thrust nut, with new rings, also as in these engines.

Install the torquemeter housing and new gasket on the crankcase front section and secure with flat washers and castellated nuts. Lockwire the nuts. Install the valve with ring, in the torque indicator housing. Install the stop screw and lock nut loosely, by hand. To obtain the proper adjustment of the stop screw, be sure that the valve is seating properly in the recess in the torque arm and that the torque arm is contacting the stop screw. The proper adjustment of the stop screw is obtained when the near edge of the valve ring is in line with the far edge of the metering slots in the valve housing sleeve, viewed from the open end of the housing. This position may be readily determined visually, using a light to assist in obtaining a fine adjustment. Tighten the stop screw until this adjustment is obtained, and then tighten the lock nut. Install the torquemeter housing cover and a new gasket, and secure with the bolts, nuts, and washers. Lockwire the nuts.

Install the booster pump drive gear and the governor drive gear in the booster pump housing. Install the booster pump housing cover and governor pump or substituting cover on the booster pump housing, using new gaskets between these parts. Secure these parts to the booster pump housing, using flat washers, plain nuts, and palnuts. Turn the booster pump drive gear by hand to check the ease of turning.

Install the booster pump housing on the crankcase front section, using new gaskets under the housing. Secure the housing to the front section and to the torque indicator housing with flat washers, castellated nuts, and cap screws. Turn the beveled booster pump drive gear inside the front section while tightening the attaching nuts and cap screws

to insure proper alignment. Lockwire the nuts and cap screws. If the booster pump drive gear does not turn easily after tightening, the trouble may usually be traced to burrs on the pilot.

**REDUCTION DRIVING GEAR** Stoning the faces of the internal teeth on the reduction driving gear is not permitted under any circumstances.

Instructions for assembly of the reduction driving gear on the crankshaft are included in the chapter entitled FINAL ASSEMBLY AND TIMING OF ENGINE, under the subtitle CRANKCASE FRONT SECTION.

**VALVE TAPPETS AND VALVE TAPPET GUIDES** Valve tappets and guides which are scored or scratched to such an extent that they may not be smoothed up by light polishing should be replaced with new parts. It is essential that a smooth finish be obtained on the outside diameter of the tappets and the inside diameter of the guides. For polishing, use Aloxite No. 320 polishing cloth, or its equivalent, and H 41 fine grade finishing compound, or its equivalent. (Refer to the section in the Appendix entitled SHOP MATERIALS.) Best results may be obtained by the use of worn polishing cloth. Do not stone the outside diameter of valve tappets or the inside diameter of tappet guides, and do not use crocus cloth and gasoline for polishing these surfaces.

Tools to be used in polishing valve tappets and guides may be made by the operator, to be used in a small, high-speed bench lathe. For polishing tappets, a draw bar or similar device for holding the tappet in the lathe is recommended. Make up a hand-polishing tool consisting of a split block, hinged on one side at the split, and provided with two handles, one in each half of the block, on the side opposite from the hinge. There should be a semicircular groove in each half of the block, forming a cylindrical hole slightly larger in diameter than the tappet when the halves of the block are brought together. Line the hole in the block with polishing cloth, apply a small quantity of finishing compound to the tappet, and polish. For polishing tappet guides, make up a hollow polishing plug, slightly smaller in diameter than the inside diameter of the tappet guide, provided with a slot in one side approximately four inches (100 mm) long. Insert a strip of polishing cloth in the slot, and wind once around the tool in the direction opposite from that of lathe rotation. Mount the polishing tool in the lathe chuck, apply a small quantity of finishing compound to the tappet guide, and polish. See figure 167.

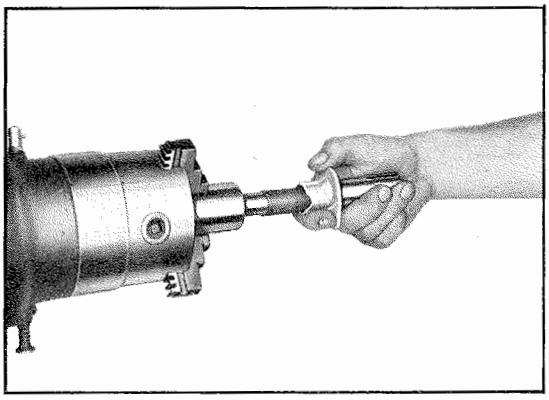


**Fig. 167. Polishing Tappet Guide Inside Diameter**

Check the outside diameter of the tappet and the inside diameter of the tappet guide after polishing using a micrometer and plug gage (Tool No. 801071), respectively. Instructions covering the inspection of these parts are included in the chapter entitled INSPECTION OF ENGINE PARTS, under the subtitle CRANKCASE FRONT SECTION.

Insure that all traces of finishing compound are removed from valve tappets and guides before assembly. Lubricate the valve tappet rollers, roller bushings, and pins with engine oil. Insert a roller bushing in its roller, and

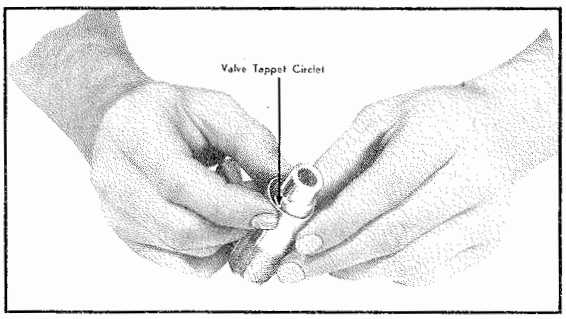



**Fig. 168. Valve Tappet Retaining Circlet on Installing Tool**

install these parts in the slotted end of the valve tappet. Install the roller pin. Lubricate the tappet and install it in its guide from the slotted end of the guide. Insure that each tappet is assembled with its respective tappet guide. Place a new tappet locking circlet on installing tool (Tool No. 83643). See figure 168. Stand the tappet and guide assembly on a bench, roller end down, place the installing tool with circlet in position in the guide, and push the circlet into the groove in the upper end of the tappet. See figure 169. Insure that the circlet is tight after installation.

Instructions for installation of the valve tappet and guide assemblies in the crankcase front section are included in the chapter entitled FINAL ASSEMBLY AND TIMING OF ENGINE, under the subtitle CRANKCASE FRONT SECTION.

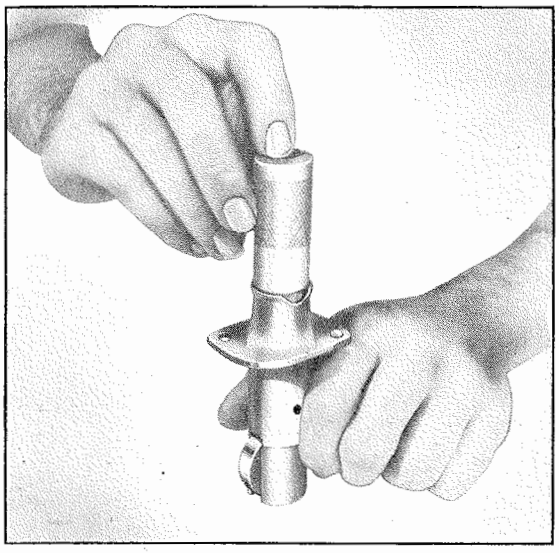


**Fig. 169. Installing Valve Tappet Retaining Circlet**

# CRANKCASE FRONT MAIN SECTION

Refer to the sections entitled REPAIR PROCEDURE and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

If retapping of the cylinder hold-down cap screw hole threads is found to be necessary, use for this purpose the tapping fixture (Tool No. 83654), tap holder (Tool No. 83653), and standard size tap (Tool No. 800214).

Clean up the threads with the standard size tap and try a standard size cap screw in the hole. If a snug fit is obtained, no oversize will be needed. However, in cases where threads are mutilated or a standard size cap screw is loose, retap the hole oversize, using tap (Tool No. 800127) for a .007 inch oversize hole and tap (Tool No. 800128) for a .012 inch oversize hole. Use these taps to clean up the threads when either a .007 inch or .012 inch oversize cap screw is to be used.

For checking the size of the crankcase cap screw holes the following gages are supplied:

standard size — Tool No. 800130
.007 inch oversize — Tool No. 800131
.012 inch oversize — Tool No. 800132

If the threads in the cylinder hold-down cap screw holes are too badly mutilated to be reconditioned by tapping, discard the crankcase. In such cases, it will be necessary to replace both front and rear halves of the crankcase main section with new parts, since these parts are matched and are not supplied separately.

If the inside diameter of the crankshaft front main bearing ring is worn by the reduction driving gear spacer oil seal rings, remove the bearing ring and grind the inside diameter oversize. To do this, set up the bearing ring in an internal grinding machine or in a lathe with a tool post grinder, and grind the bore to either .005 inch (0.127 mm) or .010 inch (0.254 mm) oversize diameter, as required. After grinding, check to make sure that the inside diameter is concentric with the outside diameter of the bearing ring. Break sharp edges at the ends of the bore to 1/64 inch (0.397 mm) after grinding. NOTE: Oversize reduction driving gear spacer oil seal rings must be used in every case with a bearing ring which has been ground oversize on the inside diameter. Use oversize rings corresponding to the bearing ring inside diameter oversize.

If the front main bearing ring was removed for reconditioning, re-install the bearing ring in the crankcase at this time. Insure that the cap screw holes in the bearing ring are exactly aligned with the drilled holes in the crankcase. It may be necessary to press

the bearing ring into place in the crankcase if a tight fit is encountered between these parts. (Refer to the applicable Table of Limits for the proper fit at this location.)

If replacement of the cam bearing ring is found to be necessary, do this in accordance with the following instructions: Use puller (Tool No. 84535) to remove the old cam bearing ring. Place the crankcase front main section on a bench so that the cam bearing ring is up. Install the puller over the bearing ring, lining up the hole in the puller ring with the locating dowel pin in the main section. Tighten the three screws into the drilled holes in the circumference of the cam bearing ring. Remove the bearing by tightening evenly the three puller screws in the puller ring against the flange of the crankcase front main section.

Clean up the outside diameter of the cam bearing ring support on the crankcase front main section. Measure the outside diameter of the support and the inside diameter of the cam bearing ring to insure that the proper fit is obtained. (Refer to the applicable Table of Limits.)

Heat the new cam bearing ring in a hot oil bath at a temperature of 300 deg. F. (149 deg. C.) for fifteen minutes. Coat the cam bearing ring support on the crankcase section with engine oil. Place the installing tool (Tool No. 800993) on the support, locating the 5/16 inch (7.94 mm) diameter hole in the tool over the dowel pin in the crankcase section. Hold the cam bearing ring, using asbestos gloves, and place over the installing tool, engaging the bearing splines correctly with the splines in the outside diameter of the tool. Press the bearing ring down so that the flange bears tightly against the crankcase. Check bottoming of the bearing ring on the crankcase by attempting to insert a .0015 inch feeler gage between these parts. Remove the installing tool after the bearing ring has cooled.

**CAM AND CAM DRIVE** Install the cam bearing ring spacer in position over the locating dowel pin in the crankcase front main section, engaging the spacer splines with the cam bearing ring splines.

Install the cam on the bearing ring after lubricating these parts thoroughly.

Assemble the intermediate governor drive gear to the cam drive gear, using six attaching screws. Align the marked teeth on the two gears. Secure the screws with lock wire.

Install the oil passage plug in the cam drive gear bracket. Install the cam drive gear spacer over the front end of the cam drive gear supporting boss on the bracket. Lubricate the cam drive gear shaft and bushing, and insert the shaft in the bushing. Install the cam drive gear pinion on the splined end of the shaft, engaging the two marked splines on the pinion with the single marked spline on the shaft. Install the cam drive gear and pinion bolt in the cam drive gear shaft from the splined end of the shaft. Tighten the nut on the bolt, using a screwdriver in the slot in the bolt head to hold the bolt, and using a torque indicating wrench on the nut. Observe the proper torque value. (Refer to the applicable Table of Limits.) Cotter the nut.

Rotate the cam so that the two marked internal teeth are in line with the vertical centerline of the crankcase front section. Install the cam drive gear bracket spacer and the cam drive gear bracket over the splined cam bearing ring spacer on the cam supporting boss on the main section. Locate these parts correctly over the dowel pin in the main section.

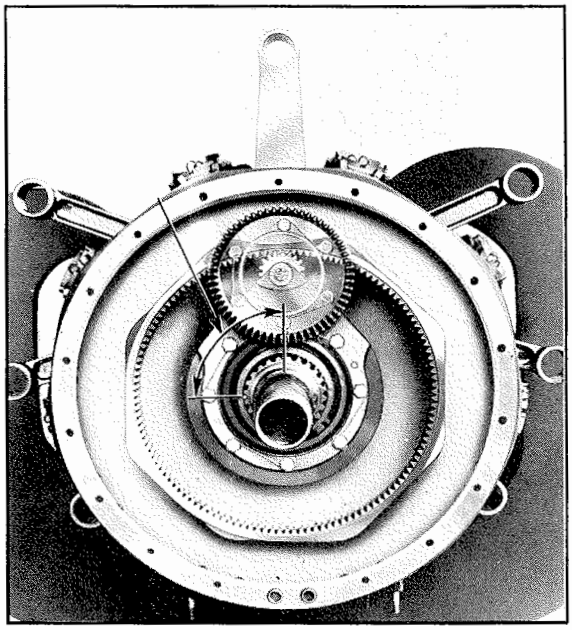


**Fig. 170. Timing Cam and Cam Pinion, Showing also Proper Location of Reduction Driving Gear Blind Spline**

Time the cam and cam drive pinion by engaging the two marked teeth on the cam and the single marked tooth on the pinion. See figure 170.

Secure the cam drive gear bracket to the crankcase front main section by installing the eight retaining screws. Tighten these screws to the proper torque value, using a torque indicating wrench. (Refer to the applicable Table of Limits.) Lockwire the screws in pairs.

# CRANKCASE REAR MAIN SECTION AND SUPERCHARGER FRONT HOUSING

Refer to the sections entitled REPAIR PROCEDURE, STUD REPLACEMENT, and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**CRANKCASE REAR MAIN SECTION** If retapping of the cylinder hold-down cap screw hole threads is found to be necessary, do this in accordance with instructions in the previous section, entitled CRANKCASE FRONT MAIN SECTION, in this chapter.

**SUPERCHARGER FRONT HOUSING** If the impeller shaft front oil seal support has been removed, install it on the housing by first placing the gasket on the front face of the supercharger front housing. Place the support on the gasket and the ring on the support. Line up the holes and insert the eight screws from the inside of the supercharger front housing. Lock the screws to the ring by staking them at the threaded end with a center punch. Avoid staking the screws at the beginning of the thread.

For honing the impeller shaft front support in the supercharger front housing, clamp housing on adapter (Tool No. 801530) using fixture (Tool No. 84294). Hold hone (Tool No. 802116) in a drill press spindle and install honing stones (Tool No. 802118). If necessary, the support may be ground to either .005 inch or .010 inch oversize and suitable rings obtained. For honing a standard size support, adjust hone to obtain a diameter of 2.192 to 2.193 inches (55.677 to 55.702 mm). When an oversize support is desired, set the assembly accordingly.

Run the spindle at approximately 50 rpm moving the hone up and down in the support. Hone only long enough to obtain a smooth surface, using kerosene, or its equivalent, as a lubricant. For a support with a standard inside diameter, check the finished hole with gage (Tool No. 801202). For an oversize support having a 2.197 to 2.198 inches (55.804 to 55.829 mm) inside diameter, check the finished hole with gage (Tool No. 801474). For an oversize support having a 2.202 to 2.203 inches (55.931 to 55.956 mm) inside diameter, check the finished hole with gage (Tool No. 801488). Blueprint 802116 will be supplied with these tools.

**ENGINE MOUNTING LUGS** Where excessive wear of the engine mounting lugs in the supercharger front housing is experienced, the engine mounting lug holes should be reworked for installation of steel flanged bushings.

Using drill, (Tool No. 84758), drill all mounting lug holes to a diameter of 41/64 inch (16.28 mm). Ream all holes to a diameter of .655-.656 inch (16.64-16.67 mm) using reamer, (Tool No. 84759), and check the diameter of the holes using gage, (Tool No. 84880). Chamfer 45 deg. to .750 inch (19.05 mm) and spotface to 1.313 inch (33.37 mm) diameter on the propeller end of the hole.

Press the proper bushings in all mounting lug holes using plug and collar, (Tool No. 84881). The complete set of tools for performing this operation is supplied under Tool No. 84882.

If bushings have already been installed in the mounting lugs and are worn, drill out the bushing, check the inner diameter of the mounting lug hole, drill to proper size, if necessary, and install new bushings as previously described.

The engine mounting bolt bushings are not

intended to correct any error in the mounting circle diameter caused by accident or other abnormal conditions. They are only intended to correct wear in the 15/32 (11.91 mm) diameter mounting lug hole.

Assemble the crankcase breather unit by installing the gasket, screen, gasket, and breather on the two attaching studs located on the top of the supercharger front housing. Secure the assembly with nuts and palnuts.

Place the crankcase rear main section front end down on a bench. Place the large rubber oil seal ring in place and lower the supercharger front housing onto the crankcase rear main section making certain that all dowels are properly aligned. Secure these two sections with 18 spherical seat washers and 18 attaching bolts.

## SUPERCHARGER REAR HOUSING AND SUPERCHARGER REAR HOUSING COVER

Refer to the sections entitled REPAIR PROCEDURE, STUD REPLACEMENT, and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

Install all oil passage plugs in the supercharger rear housing and supercharger rear housing cover.

**SUPERCHARGER REAR HOUSING** If replacement of the impeller drive gear front bushing is found to be necessary, do this using the following tools: fixture (Tool No. 84854), plug and collar (Tool No. 83865), jig (Tool No. 800441), drills (Tool No. 83790, 83791, and 83802), reamer (Tool No. 83792), adapter (Tool No. 801503), line reamer (Tool No. 83051), and plug gages (Tool No. 83793 and 83052). Instructions for performing this replacement are included on blueprint No. 84854, which is provided with this fixture.

If replacement of the copper fuel venturi extension tube is found to be necessary, do this using the set of tools (Tool No. 800064) and fixture (Tool No. 800065). Instructions for performing this replacement are included on blueprint No. 800064, which is provided with this set of tools.

If replacement of the diffuser plate is found to be necessary, do this in accordance with the following instructions: Break the lock wire securing the diffuser plate attaching nuts and remove the nuts. Lift off the diffuser plate. If a brass shim has been previously installed between the diffuser plate and the supercharger rear housing, use the same shim, or a new shim of the same thickness, under the new diffuser plate. Install a new diffuser plate, and tighten the attaching nuts to the proper torque value. (Refer to the applicable Table of Limits.) Lockwire the nuts securely.

In cases where it is found necessary to replace the diffuser plate or the supercharger front or rear housing with a new part, it is recommended that a pinch fit be obtained between the diffuser plate and the supercharger front housing. The pinch fit at this location is controlled by installing a shim or shims between the diffuser plate and the supercharger rear housing. It is not necessary to check this pinch fit at overhaul on engines in which the original diffuser plate and supercharger front and rear housings are used, since the proper pinch fit is obtained at the factory upon initial assembly of the engine.

Check the fit between the diffuser plate vanes and the supercharger front housing at assembly of an engine using a new diffuser plate or a new supercharger front or rear housing, in accordance with the following instructions: Place the diffuser plate in position on the supercharger rear housing. Insert and tighten the diffuser plate nuts, but do not lockwire the nuts at this time. Place the supercharger rear housing in position on the front housing parting flange without a gasket between. Make certain that the vanes of the diffuser plate are resting on the supercharger front housing.

Measure the clearance between the parting surfaces of the supercharger front and rear housings using two feeler gages on diametrically opposite sides of the housings. Measure the thickness of the gasket used be-

tween the supercharger front and rear housings using a micrometer, and subtract .001 inch (0.025 mm) from this measurement to allow for compressibility of the gasket. Subtract the figure thus obtained from the measured clearance between the supercharger front and rear housings. This final figure is the pinch fit which will be obtained between the diffuser vanes and the supercharger front housing when the nuts attaching the supercharger rear housing to the front housing are tightened. Refer to the applicable Table of Limits for the proper pinch fit at this location. If the figure obtained above representing this pinch fit is less than the minimum figure given in the Table of Limits, it will be necessary to install one or two diffuser plate shims, as required, to obtain the proper pinch fit.

Lift the supercharger rear housing from the front housing and remove the diffuser plate nuts and the diffuser plate. Install the shim or shims, if necessary, on the diffuser plate parting surface, and assemble the diffuser plate to the supercharger rear housing. Tighten the diffuser plate attaching nuts and lockwire securely.

If replacement of the impeller shaft rear sleeve is found to be necessary, do this in accordance with the following instructions: For engines incorporating a sleeve locked with a pin, this pin must be removed prior to removal of the sleeve. To remove locking pin, insert jig (Tool No. 800603) in the sleeve, insert the locating pin (Tool No. 800603-8) in the jig and adjust the knurled nut so that the locating pin enters the locking pin hole in the sleeve freely. Clamp the jig tight. CAUTION: With the jig clamped tight, the locating pin should be free in the pin hole. Insert drill bushing (Tool No. 800603-3) in jig. Insert the drill, (Tool No. 84455) in a drill spindle and drill into the locking pin approximately ⅛ inch (3.17 mm) deep. Replace bushing (Tool No. 800603-3) with bushing (Tool No. 800603-5), replace drill (Tool No. 84455) with drill (Tool No. 800604) and cut the head of the pin away. Make certain not to drill into the metal under the head of the pin. Remove the jig and drive out the old pin using punch (Tool No. 802183).

For removing the sleeve, place collar (Tool No. 800758) on an arbor press with the large opening up. Place the housing on the collar, with the studded side down. Insert plug (Tool No. 800602-1) in the sleeve and press the sleeve out. Clean up the bore of the housing and remove any burrs. NOTE: If the sleeve is locked with a screw, remove the screw, then proceed as above.

For installing pin-lock type sleeves, place the collar (Tool No. 800758) on an arbor press. After heating the housing to 225 deg. F. (107 deg. C.) for 1½ hours, place it on the collar with the studded side up. Insert plug (Tool No. 800602-1) in sleeve, and screw nut (Tool No. 800602-2) down on the flange of the sleeve. Insert the plug in the housing, with one of the sleeve holes in line with the top center tapped hole used for fastening the impeller shaft retainer. Press the sleeve into the housing.

For this operation where a screw lock type sleeve is used, omit the use of the collar (Tool No. 800758) and plug (Tool No. 800602-1). Drop the sleeve into the heated housing, line up the two tapped holes in the sleeve with the holes in the housing using the two plugs (Tool No. 801206) to hold the sleeve in place until tight.

To drill the lock pin hole, insert the jig (Tool No. 800603) in the sleeve. Insert the drill bushing (Tool No. 800603-4) in the jig. Retract the locating pin inside about ⅜ inch (9.53 mm). Insert locating pin (Tool No. 800-603-10) in the bushing and into the locating pin hole in the housing. Adjust the large knurled nut and clamp the jig tight. CAUTION: With the jig clamped tight the locating pin should be free in the pin hole.

Remove the locating pin and replace bushing (Tool No. 800603-4) with bushing (Tool No. 800603-3). Hold drill (Tool No. 84455) in the drill press spindle. With the housing held at a 35 deg. angle, drill the pin hole in the sleeve. Replace drill (Tool No. 84455) with reamer (Tool No. 82486) and ream the hole in the sleeve. Check the reamed hole with gage (Tool No. 82231).

Insert the locking pin in the housing and drive it in using punch (Tool No. 802183). Check to insure that the pin does not protrude into the bore of the sleeve. Peen metal around

the head of the pin using a center punch.

For grinding this sleeve, mount the fixture (Tool No. 84294) on the face plate of an internal grinder or a lathe and indicate pilot diameter and face to run true. Clamp gage bar (Tool No. 801203-1) on the front end of the housing using two screws (Tool No. 801-203-2). Clamp the housing to fixture (Tool No. 84294) using seven 3/16-24 hex nuts and seven 5/16 inch washers on the studs of the fixture. Grind the inside of the sleeve and check the size of the hole with the following gages:

Tool No. 801201 for a final finished inside diameter of 2.192 to 2.193 inch, (55.677 to 55.702 mm)

Tool No. 801473 for a final finished inside diameter of 2.197 to 2.198 inch, (55.804 to 55.829 mm)

Tool No. 801489 for a final finished inside diameter of 2.202 to 2.203 inch, (55.931 to 55.956 mm)

Hold to the lower limits wherever possible.

Grind the face of the sleeve flange and use flush pin gage (Tool No. 801205). NOTE: When the grinding is done on a lathe a portable tool post grinder is required.

For honing the inside diameter of the rear supercharger housing sleeve, place the fixture (Tool No. 84294) on a drill press table. Clamp the housing and sleeve assembly on the fixture (Tool No. 84294) using seven 5/16-24 hex nuts and seven 5/16 inch washers on the studs of the fixture. Hold the hone (Tool No. 802116) in the drill press spindle and run the spindle at about 50 rpm and hone the sleeve by moving the hone up and down in the sleeve. Hone the inside of the sleeve and check the finished hole with the following gages:

Tool No. 801202 for an inside diameter of 2.192 to 2.193 inch (55.677 to 55.702 mm)

Tool No. 801474 for an inside diameter of 2.197 to 2.198 inch (55.804 to 55.829 mm)

Tool No. 801488 for an inside diameter of 2.202 to 2.203 inch (55.931 to 55.956 mm)

Stone all sharp corners. Use a good grade of kerosene as a lubricant.

Install the umbrella-type oil seal vent in the supercharger rear housing. Cover the opening to the induction passage in the rear housing with a suitable plate drilled to pass over the carburetor adapter studs.

**IMPELLER AND IMPELLER SHAFT** If replacement of the impeller shaft front and rear bushings is found to be necessary, do this in accordance with the following instructions: Clamp fixture (Tool No. 801001) on a lathe face plate. Indicate the bore of the fixture to run true. Install adapter (Tool No. 801017) in the fixture, and install the impeller shaft in the adapter and clamp. If the impeller shaft is provided with a centering ring washer pressed into the gear end of the shaft, remove the ring using puller (Tool No. 800819) before installing the shaft in the fixture.

Bore out the old bushings to a diameter of 1.450 inches (36.83 mm), leaving a thin shell of each bushing remaining in the shaft. See figure 171. Remove the shaft from the fixture,

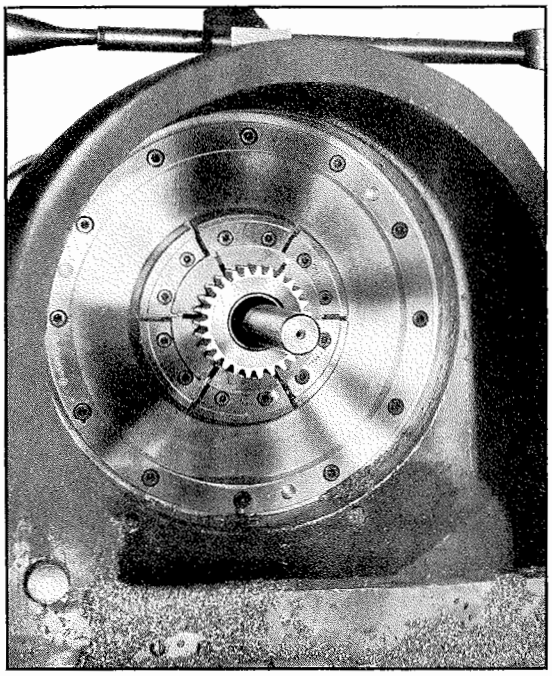


**Fig. 171. Boring Impeller Shaft Bushing**

break out the remaining shells, and clean up the bushing bores in the shaft. Check to insure that the proper tight fit of the bushings in the shaft will be obtained. (Refer to the applicable Table of Limits.)

Press in the new front bushing using press-

ing-in plug (Tool No. 800091 or Tool No. 800092). Tool No. 800091 is used for impeller shafts having an overall length of 7.36 inches (186.94 mm), and Tool No. 800092 is used for impeller shafts having an overall length of 7.26 inches (184.40 mm). Press in the new rear bushing using pressing-in plug (Tool No. 83357, Tool No. 800093, or Tool No. 800053). Tool No. 83357 is used for impeller shafts having an overall length of 7.26 inches (184.40 mm), except shafts which are provided with a centering ring washer pressed into the gear end of the shaft. Tool No. 800093 is used for impeller shafts which are provided with a centering ring washer pressed into the gear end of the shaft. Tool No. 800053 is used for impeller shafts having an overall length of 7.36 inches (186.94 mm). In all cases, when pressing in impeller shaft front and rear bushings, press in the bushing using the proper plug until the shoulder on the plug or on the bushing is bottomed on the rear end of the impeller shaft. The bushing is then installed to its proper depth.

Reinstall the impeller shaft in the lathe fixture and adapter (Tool No. 801001 and 801017), and clamp. Finish bore the bushings to a diameter of 1.3120 to 1.3130 inches (33.32 to 33.35 mm). Use plug gage (Tool No. 82371) to check the size of the bushing holes after finish boring. Use the alignment plug (Tool No. 82361) to check the alignment of the bushing holes after finish boring. Remove the impeller shaft from the fixture and remove the tools from the lathe.

If a centering ring washer pressed into the gear end of the impeller shaft is used, install the washer using pressing-in plug (Tool No. 83357).

Fit new oil seal rings in the impeller shaft front and rear oil sleeves, insuring that the proper ring side clearance and gap are obtained. (Refer to the applicable Table of Limits.)

If the bronze spherical impeller shaft thrust ring and the spherical counterbore in the impeller shaft retainer are scratched, burred, or scored, lap the mating spherical surfaces of these parts using lapping fixture (Tool No. 83870) and lap (Tool No. 83891). To lap the spherical surface on the impeller shaft retainer, attach the lap to the arbor of the fixture and attach the retainer to the body of the fixure using five screws. Install the arbor in the fixture and lap using 3M oil mix lapping compound, grade 600, or equivalent. (Refer to the section in the Appendix entitled SHOP MATERIALS.) To lap the spherical thrust ring, remove the lap from the arbor and install the thrust ring on the tapered plug on the end of the arbor. Lap the thrust ring into the retainer using the same lapping compound.

Install the bronze washer over the impeller shaft splines so that the chamfered side of the washer is against the gear. Install the impeller shaft rear oil sleeve, with rings, on the shaft so that the oil seal rings are nearest the gear. Place the impeller shaft in position in the supercharger rear housing, taking care that the oil seal rings are not damaged. Place the impeller shaft thrust ring splined washer, if used, and the spherical thrust ring on the rear end of the shaft, and install the laminated steel shim and the impeller shaft retainer on the supercharger rear housing. Tighten five flat head screws into the tapped holes in the rear housing to secure the retainer to the housing. Do not stake the screws at this time.

Check the impeller shaft end movement by inserting a feeler gage between the spherical thrust ring and the rear end of the impeller shaft or the steel splined washer, if used. (Refer to the applicable Table of Limits.) If the impeller shaft end movement is not within the specified limits, add or subtract shims from the laminated shim under the impeller shaft retainer and repeat this check. Do not stake the impeller shaft retainer attaching screws at this time, since the retainer must be removed later to permit installation of the impeller drive gear.

Press the impeller on the impeller shaft as far as possible by hand. Complete the installation of the impeller using installing tool (Tool No. 800304) and adapter (Tool No. 800307). Tighten the four screws passing through the body of the installing tool into the tapped holes in the impeller. Install the adapter on the end of the rod which passes through the impeller shaft so that the pilot

on the adapter is centered in the spherical thrust ring, and lock using the locking pin. The adapter tool should be seating on the impeller shaft retainer, and the locking pin should be seating in the semi-circular groove in the adapter. Press the impeller on the shaft by turning the screw until the impeller hub is bottomed on the rear impeller shaft oil sleeve. Remove the installing tools.

Measure the clearance between the impeller blades and the diffuser plate, when the impeller is in the extreme rear position. Obtain the measurement using a feeler gage, checking at several points around the impeller circumference. See figure 172. Deter-

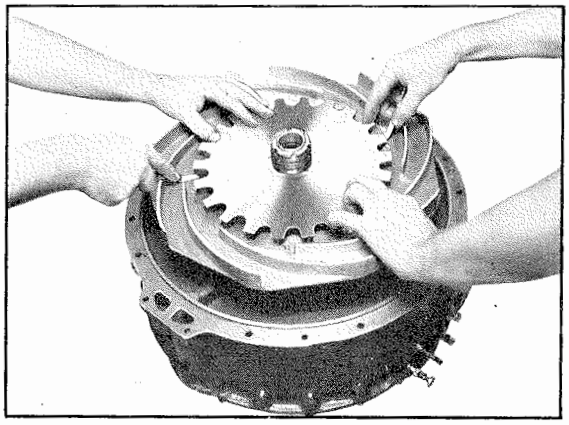


**Fig. 172. Checking Supercharger Impeller Clearance**

mine if this clearance is within the proper limits. (Refer to the applicable Table of Limits.) If the clearance is too large, remove the impeller, impeller shaft retainer, and impeller shaft, and grind the required amount from the bronze washer which is installed forward of the impeller shaft gear. If the clearance is too small, remove the impeller, impeller shaft retainer, and impeller shaft, and install a thicker bronze washer, grinding in the same manner as above if necessary to obtain the proper clearance. In either case, check again the end movement of the impeller shaft, in the same manner as previously described, before pressing on the impeller. Changing the width of the bronze impeller shaft gear washer may change the impeller shaft end movement so that it is not within the proper limits. When the proper clearances have been obtained, proceed with the assembly of the supercharger rear housing.

Install the front impeller shaft oil sleeve, with rings, on the impeller shaft so that the oil seal rings are nearest the threaded end of the shaft. Install the impeller nut lock and the impeller front nut. Lock the impeller using the impeller holding tool (Tool No. 802395) and adapter (Tool No. 84534). Tighten the impeller front nut using lug wrench (Tool No. 802275). Bend one tab of the impeller nut lock into a slot in the nut. Remove the tools from the supercharger rear housing.

**SUPERCHARGER REAR HOUSING COVER** If replacement of any of the bushings in the supercharger rear housing cover is found to be necessary, do this using the set of tools (Tool No. 83871). This set of tools contains all the tools necessary for replacing all bushings in the supercharger rear housing cover. The use of the fixtures and tools included in this set insures that the proper location of bushing holes will be obtained upon installation of new bushings. This is extremely important in order that the accessory driving gears which pilot in the bushings will be properly aligned and meshed. For location of bushings refer to figure 173.

When a bushing is removed from the supercharger rear housing cover, clean the bushing hole in the cover using crocus cloth and gaso-

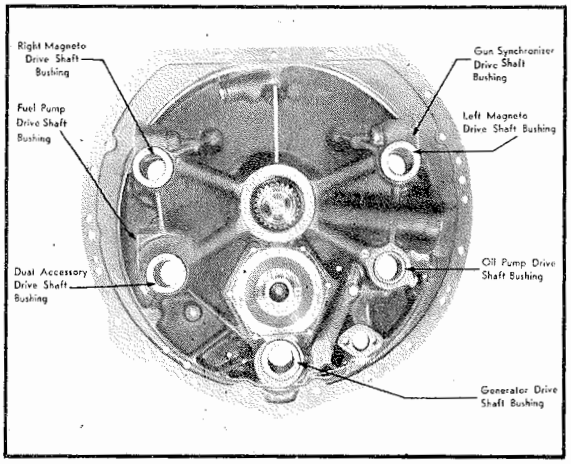

Right Magneto Drive Shaft Bushing
Gun Synchronizer Drive Shaft Bushing
Fuel Pump Drive Shaft Bushing
Left Magneto Drive Shaft Bushing
Dual Accessory Drive Shaft Bushing
Oil Pump Drive Shaft Bushing
Generator Drive Shaft Bushing

**Fig. 173. Location of Bushings in Supercharger Rear Housing Cover**

line. Inspect the oil passages and grooves for cleanliness. Insure that the proper fit of the new bushing in the bushing hole in the cover is obtained. (Refer to the applicable Table of Limits.) Lubricate the outside diameter of each bushing with engine oil before pressing the bushing into the rear cover.

**ACCESSORY DRIVE AND STARTER SHAFT BUSHING** If replacement of the accessory drive and starter shaft bushing is found to be necessary, remove the bushing using puller (Tool No. 83872). Install the locating plate on the starter pad on the rear cover, locate the pilot on the tool in the bushing bore, and turn the puller screw to push out the old bushing.

Press in the new bushing using installing tools (Tool No. 83875-1 and 83907-19), in an arbor press. Support the rear cover on collar (Tool No. 83907-18) during this operation to prevent damaging the starter attaching studs. Insure that one of the three openings in the bushing is lined up with the oil passage which leads to the Cuno oil filter hole, in order that the oil flow will not be restricted in this location.

To ream the bushing bore to size, attach the rear cover to fixture (Tool No. 82207) by means of the starter attaching studs, with locating disks (Tool No. 83907-1, -2, and -3) and locating pins (Tool No. 83907-4) in place. Install the roughing reamer (Tool No. 83886-1), in its slip bushing (Tool No. 83907-13), and insert the slip bushing in the fixture, insuring that it enters the locating disk. Ream the bushing bore by hand. See figure 174. Ream using the finishing reamer (Tool No. 83886-2) and the same slip bushing in the same manner. Check the bushing bore for size using plug gage (Tool No. 83878-1).

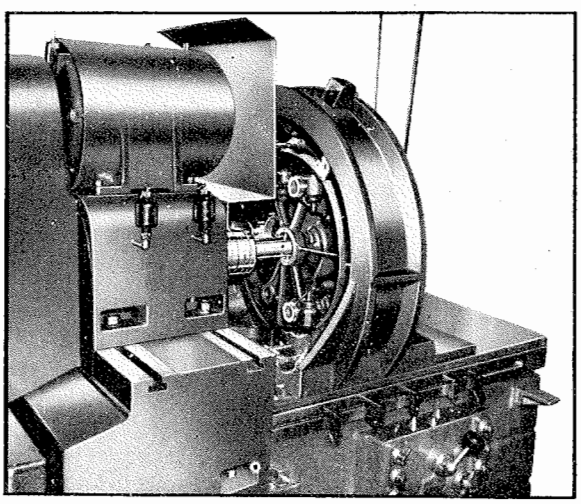


**Fig. 174. Reaming Starter Shaft Bushing**

**MAGNETO DRIVE GEAR SHAFT BUSHING** If replacement of either of the magneto drive gear shaft bushings is found to be necessary, it is first necessary to remove the gun-synchronizer drive shaft thrust bushing. This thrust bushing will interfere with the magneto drive gear shaft bushing upon removal unless it is removed first. Drill through the thrust bushing using a standard $^{11}/_{16}$ inch diameter drill and drill bushing (Tool No. 83907-17). See figure 175. Tap the drilled

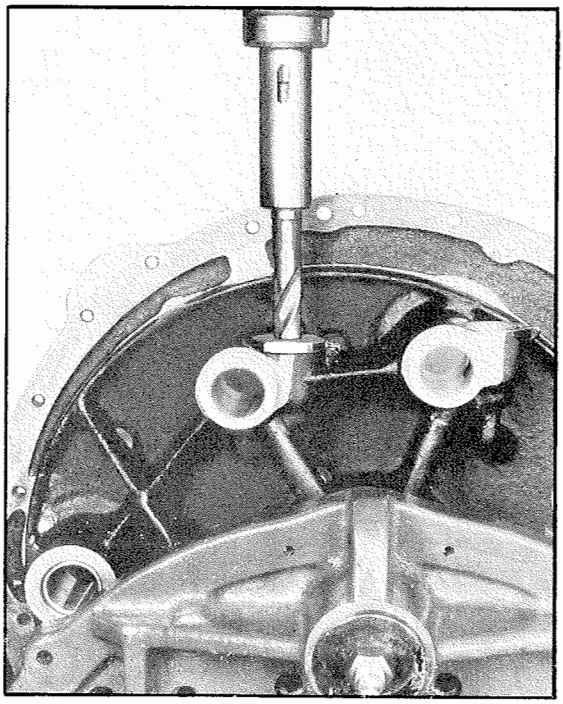


**Fig. 175. Drilling Fuel Pump Drive Shaft Thrust Bushing**

hole using a standard ¾-16 tap. Remove the thrust bushing using puller (Tool No. 83907-15, -16, and -17). See figure 176. Press out the magneto drive gear shaft bushing using plug (Tool No. 83907-20) and collar (Tool No.

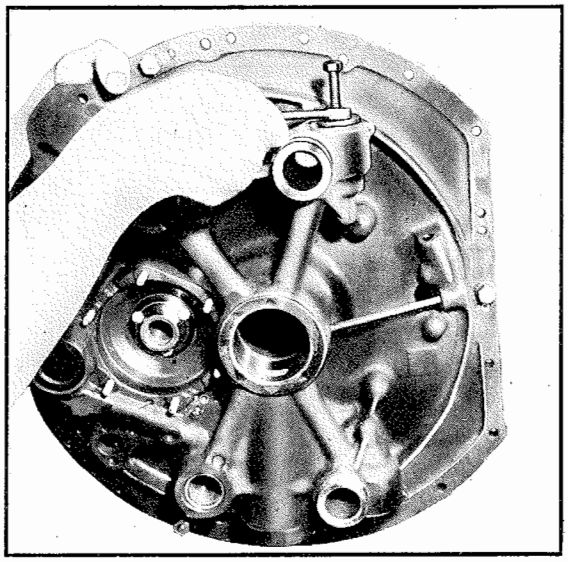


**Fig. 176. Pulling Fuel Pump Drive Shaft Thrust Bushing**

83907-24), in an arbor press. See figure 177.

Press in the new bushing using installing tools (Tool No. 83907-20 and -23), in an arbor press. Support the rear cover on collar (Tool No. 83875-4) during this operation to

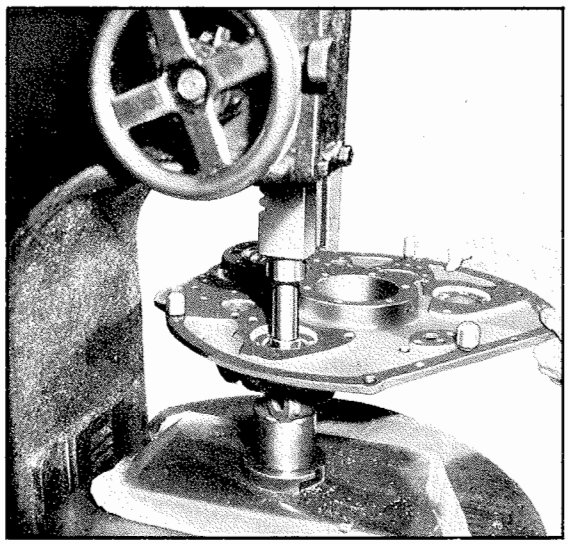


**Fig. 177. Pressing Out Magneto Drive Gear Shaft Bushing**

protect the magneto attaching studs. See figure 178.

It is necessary to machine a quarter-cut in the new bushing in the location of the gun

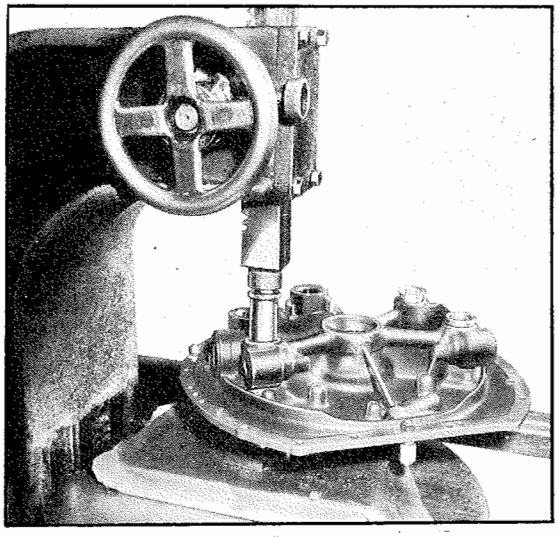


**Fig. 178. Pressing In Magneto Drive Gear Shaft Bushing**

synchronizer drive shaft. Attach the rear cover to fixture (Tool No. 82207) by means of the magneto attaching studs, with locating pins (Tool No. 83907-4), spacers (Tool No. 83879-1, -3, and -4), and screws (Tool No. 83879-10) in place. Clamp the fixture to a drill press table so that the gun synchronizer drive shaft support pilot is located directly under the drill press spindle. Install roughing cutter (Tool No. 83910-1) in the spindle of the drill press and quarter-cut the bushing. Repeat this operation using finishing cutter (Tool No. 83910-2).

Remove the fixture and rear cover together from the drill press and ream the bushing bore to size. Install the roughing reamer (Tool No. 83909-1) in its slip bushing (Tool No. 83907-12), install the slip bushing and reamer in the fixture, and ream the bushing bore by hand. Ream, using the finishing reamer (Tool No. 83909-2) and the same slip bushing in the same manner. Check the bushing bore for size using plug gage (Tool No. 83908).

Press in the new gun synchronizer drive shaft thrust bushing.

**DUAL ACCESSORY DRIVE GEAR SHAFT BUSHING** If replacement of the dual accessory drive gear shaft bushing is found to be necessary, do this in the same manner, using the same

tools, as previously described for the magneto drive gear shaft bushings. First remove the fuel pump drive shaft thrust bushing, then press out the dual accessory drive gear shaft bushing. Press in, quarter-cut, and ream the new bushing, and press in a new thrust bushing.

**OIL PUMP DRIVE GEAR SHAFT BUSHING** If replacement of the oil pump drive gear shaft bushing is found to be necessary, remove the old bushing using plug (Tool No. 83907-20) and collar (Tool No. 83907-21), in an arbor press. Press in a new bushing using installing tools (Tool No. 83907-20, -22, and -23), in an arbor press. Support the rear cover on collar (Tool No. 83907-21) during this operation to protect the oil pump attaching studs. Insure that the oil groove in the bushing is aligned with the oil feed passage in the rear cover.

To ream the bushing bore to size, attach the rear cover to fixture (Tool No. 82207) by means of the oil pump attaching studs, with spacer (Tool No. 83879-2) in place. Install the roughing reamer (Tool No. 83909-1) in its slip bushing (Tool No. 83907-12), install the tools in the fixture, and ream the bushing bore by hand. Ream using the finishing reamer (Tool No. 83909-2) and the same slip bushing in the same manner. Check the bushing bore for size using plug gage (Tool No. 83908).

**GENERATOR DRIVE GEAR BUSHING** If replacement of the generator drive gear bushing is found to be necessary, remove the old bushing using plug (Tool No. 83875-2 and 83907-20). Support the rear cover on collar (Tool No. 83875-3) during this operation to protect the generator attaching studs. Insure that the oil groove in the bushing is aligned with the oil feed passage in the rear cover.

To ream the bushing bore to size, attach the rear cover to fixture (Tool No. 82207) in the same manner as previously described for reaming the accessory drive and starter shaft bushing. Install roughing reamer (Tool No. 83909-1) in its slip bushing (Tool No. 83907-12). Install these tools in the fixture, insuring that the slip bushing enters its locating disk. Ream the bushing bore by hand. Ream using the finishing reamer (Tool No. 83909-2) and the same slip bushing in the same manner. Check the bushing bore for size using plug gage (Tool No. 83908).

**INTERMEDIATE IMPELLER DRIVE SHAFT REAR BUSHING** If replacement of the intermediate impeller drive shaft rear bushing is found to be necessary, remove the bushing using puller (Tool No. 800691), after removing the three attaching screws. Press in the new bushing using installing tool (Tool No. 800781-1). Take care to align the screw holes in the bushing with the tapped holes in the rear cover using the locating pin (Tool No. 800781-2). The screw holes in the bushing and rear cover are unequally spaced. Support the rear cover on suitable blocks during these operations to prevent damaging the studs on the rear side of the rear cover.

To ream the bushing bore to size, attach the fixture (Tool No. 83873) to the rear cover, locating the two pilots on the fixture in the generator drive gear bushing and the accessory drive and starter shaft bushing. Tighten the nuts and washers on the three studs on the fixture to secure the fixture to the rear cover. Attach the rear cover to fixture (Tool No. 82207). Install the roughing reamer (Tool No. 83876-1) in its slip bushing (Tool No. 83907-12), install these tools in the fixture, and ream the bushing bore by hand. Ream using the finishing reamer (Tool No. 83876-2) and the same slip bushing in the same manner. Check the bushing bore for size using plug gage (Tool No. 83877).

**ACCESSORY DRIVE AND STARTER SHAFT** Place the accessory drive gear on the accessory drive and starter shaft, and turn the gear to engage the internal lugs on the gear with the mating ears on the shaft. Install these parts, gear end up, in holding fixture (Tool No. 84375-1), held in a vise. Install locating plug (Tool No. 84375-7) between two of the ears on the shaft. Place a spring and pin assembly

in the clamping plate (Tool No. 84375-11), and compress the spring by tightening the clamp. Place the clamping plate over the end of the shaft, allowing the knurled handle of the locating plug to extend into the hole in the plate. Install the bushing (Tool No. 84375-6) in the clamping plate, over the end of the shaft, centralizing the shaft in the plate. Using the installing tool (Tool No. 84375-13), rap the springs and pins into place. See figure 179. Repeat this operation to install the remaining springs and pins, after removing the locating plug.

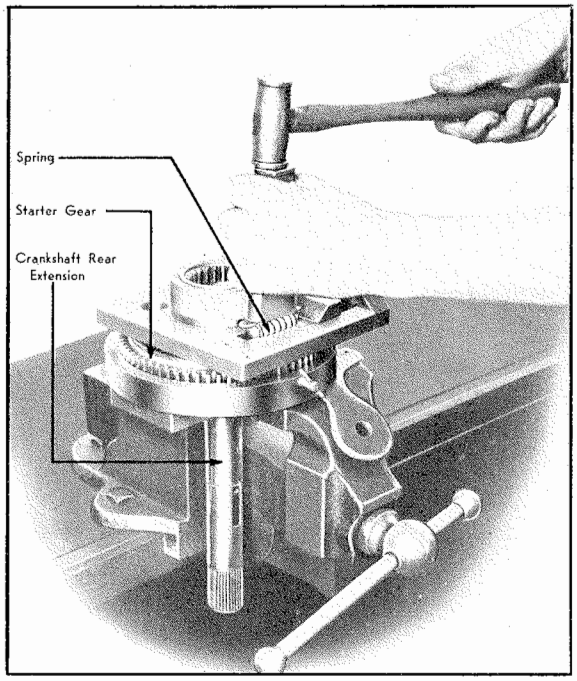



**Fig. 179. Assembling Accessory Drive and Starter Shafts**

Attach the accessory drive gear rear plate to the shaft, using the five screws. Lockwire the screws in groups of three and two.

**SINGLE-SPEED IMPELLER DRIVE** In engines equipped with a single-speed impeller drive, proceed with the assembly of the supercharger rear housing and cover as follows: Assemble the magneto drive gears and the dual accessory drive gear to their respective shafts by installing the attaching screws. Insure that the proper cap screws are used. The proper screws for use in these locations are ⅜ inch (9.53 mm) long, measured from the underside of the screw head to the end of the thread. Lockwire the screws in pairs.

Place the supercharger rear housing, rear end up, on an assembly and disassembly stand, also used in the disassembly of the supercharger rear housing and cover. Before installing the impeller drive gear and pinion in position in the bushing in the rear housing, it is necessary to remove the impeller shaft retainer, which was previously assembled to the rear housing in order to check the impeller shaft end movement. Remove the impeller shaft retainer attaching screws and the retainer, install the impeller drive gear and pinion in its bushing in the rear housing, and reinstall the retainer and attaching screws. Stake the attaching screws into the retainer after tightening, to prevent loosening of the screws. Fit a new oil seal ring in the groove in the impeller shaft retainer, insuring that the proper ring side clearance and gap are obtained. Install the bronze accessory drive and starter shaft thrust ring in the recess in the impeller shaft retainer.

Install the accessory drive and starter shaft in position in the impeller shaft, meshing the accessory drive gear with the impeller drive pinion. Take care to insure that the splines on the front end of the accessory drive and starter shaft do not scratch or score the impeller shaft bushings, and that the impeller shaft retainer oil seal ring is not damaged.

Check the end movement of the accessory drive and starter shaft at this time. To do this, install the supercharger rear housing cover and gasket temporarily, and secure with three attaching nuts on each side. Locate a dial indicator on the rear cover so that the indicator spindle contacts the end of the accessory drive and starter shaft. Move the shaft up and down by hand, holding the end of the shaft which extends through the impeller shaft. See figure 180. Note the difference in the indicator readings, which is the end movement of the shaft. (Refer to the applicable Table of Limits.) If the end movement is too small, grind the required amount from the bronze accessory drive and starter shaft thrust ring. If the end movement is too

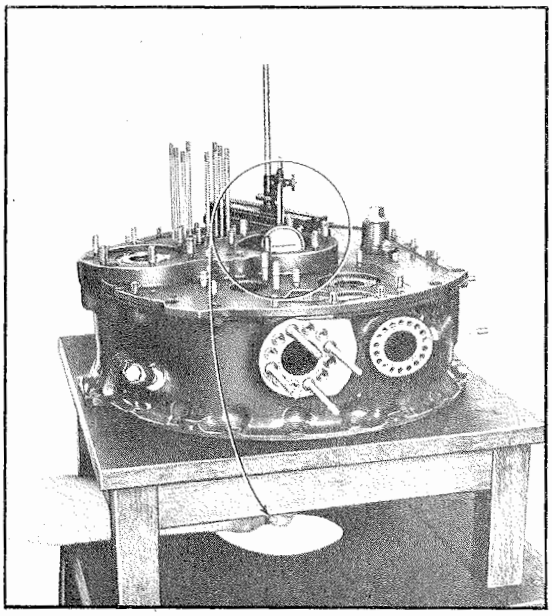


**Fig. 180. Checking Accessory Drive and Starter Shaft End Clearance**

great, install a new thrust ring. When the proper end movement is obtained, remove the supercharger rear housing cover.

Place the oil pump drive gear and the dual accessory drive gear in position in the supercharger rear housing, meshing these gears with the accessory drive gear. Place the magneto drive gears in position, meshing these gears with the oil pump drive gear and the dual accessory drive gear. Place the generator drive gear in position, meshing this gear with the impeller drive pinion.

Insure that the parting surfaces of the supercharger rear housing and cover are clean and smooth. Install new gaskets on the supercharger rear housing rear parting surface and on the rear housing oil suction flange. Hold the supercharger rear housing cover in position over the rear housing. Place a fiber drift through the generator drive gear bushing in the rear cover, and enter the end of the drift into the rear end of the generator drive gear shaft. Use of the drift will assist in entering the generator drive gear shaft in its bushing in the rear cover when the rear cover is lowered. Lower the rear cover onto the supercharger rear housing, taking care to insure that the ends of all shafts in the rear housing enter their respective bushings in the rear cover. See figure 181.

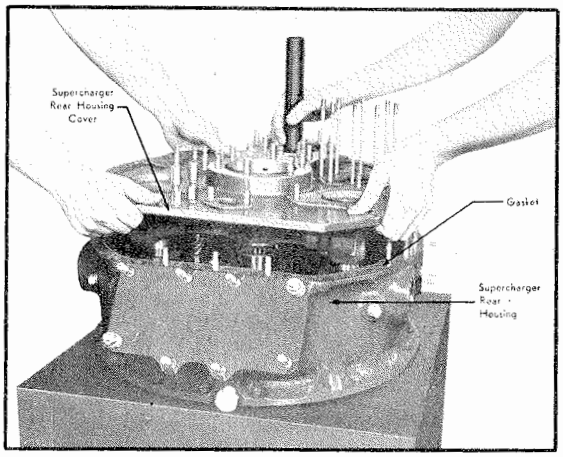



**Fig. 181. Installing Supercharger Rear Housing Cover**

To secure the supercharger rear housing cover to the rear housing, install flat washers and plain hexagonal nuts on all rear cover attaching studs except those which also serve for attachment of the magnetos, oil pump, and dual accessory drive housing. Use a torque indicating wrench when tightening these nuts and observe the proper torque value. (Refer to the applicable Table of Limits.) Lock the nuts with palnuts. Install the flat head machine screws in all countersunk holes in the rim of the rear cover except those in the dual accessory drive housing mounting pad, and install flat washers, plain nuts and palnuts on the screws. Install the three slotted round nuts under the generator mounting pad using wrench (Tool No. 83381). Install the three puller hole plugs and gaskets in the tapped holes in the rim of the rear cover.

Install the two-speed clutch oil control valve substituting cover and gasket on the rear cover, and secure with three flat washers, plain hexagonal nuts, and palnuts.

**TWO-SPEED IMPELLER DRIVE (PLATE-CLUTCH TYPE)**

In engines equipped with a two-speed impeller drive of the plate-clutch type proceed with the repair and assembly of the supercharger rear hous-

ing and cover as follows, after assembly of the accessory drive and starter shaft.

Assemble the low-speed clutch in accordance with the following instructions: Place the low-speed clutch sleeve in position over the attaching studs on the front side of the supercharger rear housing cover. Fit a new piston ring in the low-speed clutch piston, insuring that the proper ring side clearance and gap are obtained. (Refer to the applicable Table of Limits.) Install the piston and ring assembly in the low-speed clutch sleeve, fitting the inside diameter of the piston on the protruding end of the intermediate impeller drive shaft rear bushing, and meshing the serrations in the outside diameter of the piston with the internal serrations in the sleeve.

Installing tool (Tool No. 84692) is used to assist in the assembly of the low-speed clutch release spring. Loosely screw the tapered end of the bolt provided with this tool into the fiber body of the tool. Insert the body of the tool into the bronze intermediate impeller shaft rear bushing in the rear cover. Tighten the bolt in the split fiber body sufficiently to hold the body in the bushing against the pressure of the spring, when installed. See figure 182.

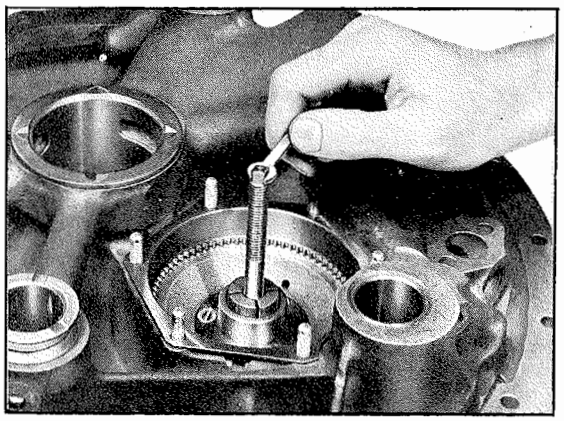


**Fig. 182. Assembling Low Ratio Clutch (Tool in Position)**

Place the low-speed clutch release spring over the installing tool and into the annulus in the hub of the piston. Place the conical bronze spacer on the spring, with the small diameter of the spacer extending inside the spring. Install the thrust washer on the spacer with the lugs down. Install the sun gear on the thrust washer, large end down. Push the sun gear down, compressing the spring, and at the same time mesh the six lugs on the thrust washer with the slots in the piston lock. Hold the parts in this position and screw the knurled nut (Tool No. 84692-3) on the assembly bolt. See figure 183.

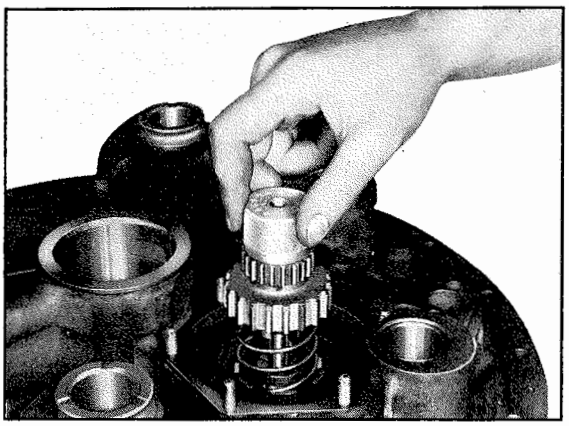


**Fig. 183. Attaching Nut to Assembly Tool**

Lubricate the low-speed clutch disks and plates with clean engine oil, and install one disk over the splines of the sun gear so that the shouldered side of the disk is nearest the piston. Next install one flat steel plate, either side down. Install in succession another disk, another plate, and the last disk in the same manner. Align the lugs on the outside diameter of the plates so that they will mesh with the slots in the rim of the low-speed clutch housing, when installed. Install the housing, and secure to the attaching studs in the rear cover by six flat washers and castellated nuts. Use a torque indicating wrench when tightening the nuts, and observe the proper torque value. (Refer to the applicable Table of Limits.) Do not cotter the nuts at this time, since it may be necessary to disassemble the low-speed clutch in order to adjust the intermediate impeller drive shaft end movement. Remove the installing tool.

Assemble the high-speed clutch in accordance with the following instructions: Place the high-speed clutch gear in the holding fixture (Tool No. 84668) and clamp the fixture

in a vise. Fit a new piston ring in the high-speed clutch piston, insuring that the proper ring side clearance and gap are obtained. (Refer to the applicable Table of Limits.) If it is found necessary to increase the gap of this ring, remove the required amount of metal from the end of the ring opposite the rectangular notch. Install the piston and ring assembly in the gear, insuring that the six driving lugs on the piston are inserted in the slots in the gear. Place the splined adapter on the piston with the shouldered end down.

Lubricate the high-speed clutch disks, plates, and retainer with clean engine oil, and install one bronze disk over the splines of the adapter with the tapered hub facing away from the piston. Next install one steel plate, with the recessed side facing away from the piston and with the flats in the splines aligned with the slots in the gear. Install in succession another disk, another plate, and the last disk in the same manner. Finally, install the retainer, with the tapered recess facing away from the piston and with the flats in the splines aligned with the slots in the gear. Insert the end of a length of spring-steel wire in the annulus formed by the grooves in the high-speed clutch gear and retainer. Use spring-steel wire having a diameter of 3/32 inch (2.38 mm). Start the spring-steel wire into the annulus at the widest slot in the gear, and push it through the annulus until it emerges in the same slot in which it was started. See figure 184. Bend the ends of the wire outward from the notch

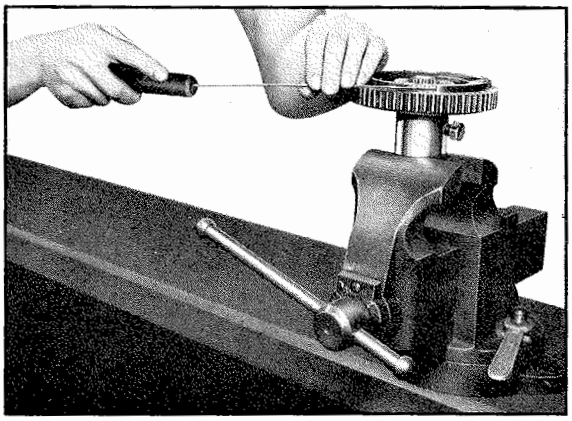


**Fig. 184. Installing Spring Steel Wire (High Ratio Clutch)**

to a 30 deg. to 40 deg. angle in order to prevent the wire from sliding in the housing. Do not bend the wire sharply around the edges. Cut the wire so that it is flush with or slightly below the contour of the shoulder on the gear. Remove the gear from the fixture.

Install the check valve and spring in the front end of the intermediate impeller drive shaft. Install and tighten the pipe plug in the threads in the shaft, over the check valve spring. Check the valve for leakage under pressure in the following manner: Hold the front end of the intermediate impeller drive shaft in gasoline, and apply an air pressure of 6 pounds per square inch (0.42 kg./sq.cm.) at the rear end of the shaft. If leakage is noted, evidenced by bubbling of the gasoline, it will be necessary to lap the valve into its seat.

Place the intermediate impeller drive shaft in holding fixture (Tool No. 800763). Install the sun gear floating bronze bushing over the rear end of the intermediate impeller drive shaft, so that the flanged end of the bushing contacts the pinion carrier. Install the pinion bushings and pinions on the carrier trunnions on the shaft, with the chamfered end of the bushings and the shouldered end of the the top of the pinion trunnions, with the open end of the locks away from the shaft. See figure 185. CAUTION: Do not install the locks pinions at the base of the trunnions. Insert the pinion horseshoe locks in the grooves at with the open end toward the shaft, since they will then come out of their grooves during operation, due to centrifugal force.

Remove the intermediate impeller drive shaft assembly from the holding fixture.

The high-speed clutch gear and intermediate impeller drive shaft have been factory-mated to obtain minimum run-out and are suitably marked to permit reassembly in their original positions. One of these marks is located on one of the high-speed clutch gear teeth at the center of one of the slots in the gear, and the other mark is located on the top of one of the intermediate impeller drive shaft pinion trunnions.

If either the high-speed clutch gear or the intermediate impeller drive shaft has been removed or the mating marks are not visible,

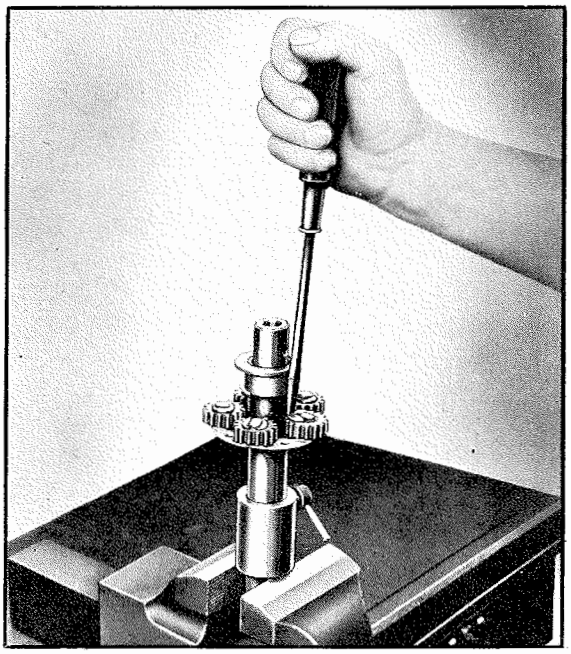


**Fig. No. 185. Installing Intermediate Impeller Pinion Gear Locks**

install the splined end of the assembled intermediate impeller drive shaft into the high-speed clutch assembly, and mount these parts on V-blocks. Clamp the rear end of the shaft lightly on the sun gear floating bushing to allow the shaft to turn. Place an adjustable V-block between the pinion supporting flange and high-speed clutch, and level the assembly. Measure the amount of runout of the high-speed clutch gear journal using a dial indicator placed near the front face of the gear. See figure 186. Note this reading. Remove the high-speed clutch gear from the intermediate impeller drive shaft, install it in the next spline location and again measure the runout. Repeat this procedure until the point of minimum runout is obtained, and mark by acid etching one tooth of the high-speed clutch gear at the center of one of the slots in the gear. Place the mating acid etch mark across the top of the pinion trunnion directly in line with the marked tooth.

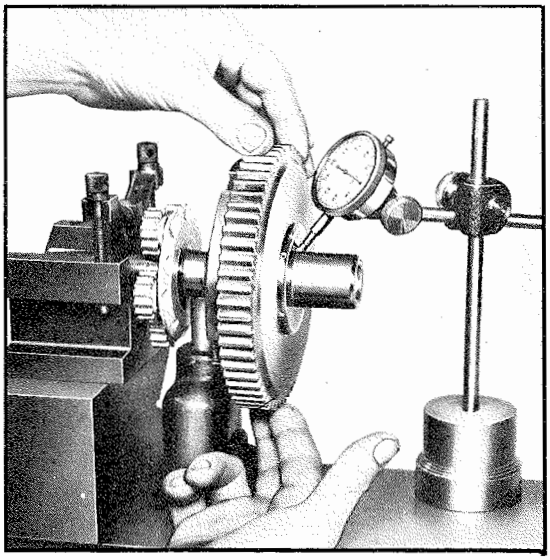


**Fig. 186. Checking High Ratio Clutch Gear Alignment**

Remove the assembly from the V-blocks. Remove the intermediate impeller drive shaft from the high-speed clutch gear.

If replacement of the intermediate impeller drive gear bushing is found to be necessary, use for this purpose the following tools: Drill jig and drill bushings (Tool No. 84321), removing and installing plug and collars (Tool No. 83019), lock pin hole reamer (Tool No. 84322), lock pin hole plug gage (Tool No. 83793), boring fixture (Tool No. 83961), plug gage (Tool No. 83023), and the set of tools (Tool No. 801009). Detailed instructions for replacing, pinning, and finish boring this bushing are included on blue print No. 801-009, which is furnished with the set of tools.

Place the supercharger rear housing, rear end up, on an assembly and disassembly stand, also used in the disassembly of the supercharger rear housing and cover. Before installing the high-speed clutch gear in position in the bushing in the rear housing, it is necessary to remove the impeller shaft retainer, which was previously assembled to the rear housing in order to check the impeller shaft end movement. Remove the impeller shaft retainer attaching screws and the retainer, install the high-speed clutch gear in its bushing in the rear cover, and reinstall the retainer and attaching screws. Stake the attaching screws into the retainer after tightening. Fit a new oil seal ring in the groove in the impeller shaft retainer. Install the bronze accessory drive and starter shaft thrust ring in the recess in the retainer in the same manner as previously described for engines having a single-speed impeller drive.

Install the accessory drive and starter shaft in position in the impeller shaft. Take care

to insure that the splines on the front end of the accessory drive and starter shaft do not scratch or score the impeller shaft bushings, and that the impeller shaft retainer oil seal ring is not damaged.

Measure the clearance between the front face of the accessory drive gear and the rear face of the high-speed clutch gear, using a feeler gage, with both gears in the extreme forward position. See figure 187. Record this

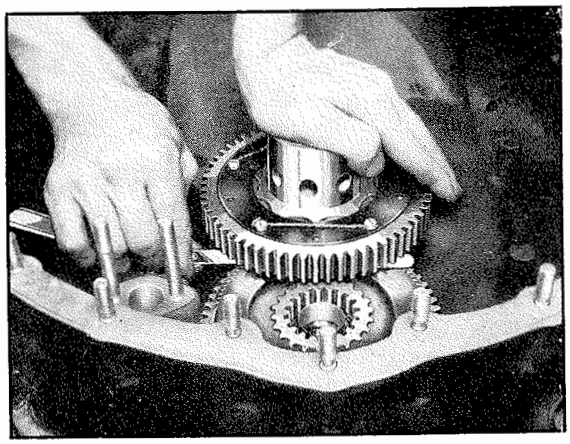


**Fig. 187. Checking Accessory Drive and High Ratio Clutch Gear Clearance**

measurement for later use in determining the minimum clearance which could exist between these gears. The limits specified in the Table of Limits refer to the minimum clearance, with the accessory drive gear in its extreme forward position and the intermediate impeller drive gear in its extreme rear position.

Place the high-speed clutch release spring in position in the splined adapter. Install the bell-shaped intermediate impeller drive gear on the intermediate impeller drive shaft, meshing this gear with the five pinions. Install the intermediate impeller drive gear and shaft together in the high-speed clutch gear. Engage the splines on the end of the shaft with the internal splines in the gear, and mesh the intermediate impeller drive gear external teeth with the accessory drive gear teeth and with the internal teeth in the high-speed clutch adapter. Insure that the marked trunnion on the intermediate impeller drive shaft is aligned with the marked tooth on the high-speed clutch gear. Screw the checking rod (Tool No. 84761) into the tapped hole in the end of the intermediate impeller drive shaft.

Check the end movement of the accessory drive and starter shaft and the end movement of the intermediate impeller drive shaft at this time, before installing the accessory driving gears in the rear housing. To do this, install the supercharger rear housing cover and gasket temporarily, and secure with three attaching nuts and washers in each side. Allow the checking rod to extend through the tapped hole in the rear cover directly behind the intermediate impeller drive shaft rear bushing. Check the end movement of the accessory drive and starter shaft in the same manner as previously described for engines having a single-speed impeller drive. Adjust the end movement if it is not within the specified limits.

Check the end movement of the intermediate impeller drive shaft in the following manner: Install the collar on the checking rod, and lock by tightening the lock screw. Screw the knurled handle on the end of the rod. Install a dial indicator on a surface gage, and adjust the position of the indicator so that the indicator spindle contacts the upper side of the collar on the checking rod. Move the intermediate impeller drive shaft up and down as far as possible by moving the checking rod, holding the knurled handle. See figure 188. Note the difference in the indicator readings,

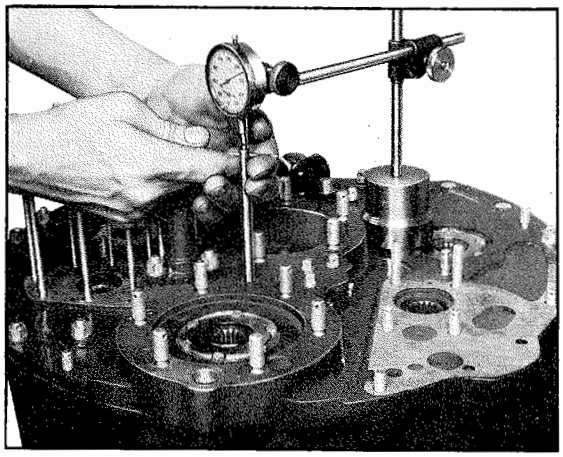


**Fig. 188. Checking Intermediate Impeller Drive Shaft End Clearance**

which is the end movement of the shaft. Insure that this end movement is greater than the minimum permissible. (Refer to the applicable Table of Limits.)

Determine the minimum clearance which could exist between the accessory drive gear and the high-speed clutch gear. The minimum clearance is obtained when the accessory drive gear is in its extreme forward position and the intermediate impeller drive gear is in its extreme rear position. To determine this clearance subtract the end movement of the intermediate impeller drive shaft from the clearance between the accessory drive gear and the high-speed clutch gear, previously measured, when both gears were in the extreme forward position. Insure that the resulting figure is greater than the minimum permissible. (Refer to the applicable Table of Limits.) If the end movement of the intermediate impeller drive shaft is too small, remove the rear cover and the low-speed clutch housing and grind the required amount from the conical bronze spacer located at the front end of the low-speed clutch release spring. If the minimum clearance between the accessory drive gear and the high-speed clutch gear is too small, remove the rear cover and the low-speed clutch housing and install a thicker spacer, grinding in the same manner as above if necessary to obtain the proper clearance. In either case, check again the end movement of the intermediate impeller drive shaft and determine again the minimum clearance between the accessory drive gear and the high-speed clutch gear before proceeding with the assembly. When the proper clearances have been obtained, remove the supercharger rear housing cover and remove the checking rod. Remove the intermediate impeller drive gear and shaft in order to permit installation of the generator drive gear.

Secure the nuts attaching the low-speed clutch housing to the supercharger rear housing cover by installing cotter pins in the nuts. Assemble the magneto drive gears and the dual accessory drive gear to their respective shafts in the same manner as previously described for engines having a single-speed impeller drive.

Place the oil pump drive gear and dual accessory drive gear in position in the supercharger rear housing, meshing these gears with the accessory drive gear. Place the magneto drive gears in position, meshing these gears with the oil pump drive gear and the dual accessory drive gear. Place the generator drive gear in position in the rear housing. With the splined high-speed clutch adapter in position in the high-speed clutch assembly, and with the high-speed clutch release spring in the adapter, install the intermediate impeller drive gear and shaft together. Engage the splines on the end of the shaft with the internal splines in the high-speed clutch gear, and mesh the intermediate impeller drive gear with the accessory drive gear, the generator drive gear, and the high-speed clutch adapter. See figure 189. Insure that the

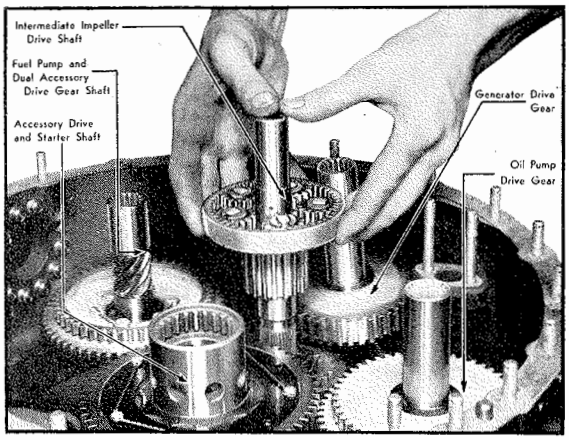

Intermediate Impeller Drive Shaft
Fuel Pump and Dual Accessory Drive Gear Shaft
Accessory Drive and Starter Shaft
Generator Drive Gear
Oil Pump Drive Gear

**Fig. 189. Installing Intermediate Impeller Drive Shaft and Pinion Gear Assemblies**

marked trunnion on the intermediate impeller drive shaft and the marked tooth on the high-speed clutch gear are aligned.

Install the supercharger rear housing cover on the rear housing and attach the rear cover to the rear housing in the same manner as previously described for engines having a single-speed impeller drive.

Lubricate and install the two-speed clutch control valve bronze sleeve in its recess in the rear cover, with the end in which a flat is machined facing towards the rear. Place the valve spring, valve spring washer, and inner and outer valve stem packing rings on the valve stem. Lubricate and install the valve

assembly in the control valve housing. Push the valve in against the spring tension and install a spacer and nut on the threaded end of the valve stem. Tighten the nut against the spring tension until the valve is in the high-speed ratio, or retracted, position.

Place a new gasket on the supercharger rear cover, install the control valve assembly, and secure with plain washers and elastic stop nuts. Remove the nut and spacer from the valve stem. Check the operation of the valve for full travel and freedom from binding.

**TWO-SPEED IMPELLER DRIVE (ROLLER-CLUTCH TYPE)** On engines equipped with a two-speed impeller drive of the roller-clutch type, proceed with the repair and assembly of the supercharger rear housing and cover as follows after the assembly of the accessory drive and starter shaft:

Install the high-speed clutch sleeve in its recess in the rear cover. It may be necessary to tap the sleeve into place with a fiber mallet. When the flange of the sleeve seats against the rear cover, check the gap of the piston ring in the sleeve. Make sure that the ring is not seating in the radius at the bottom of the sleeve. To insure this, it is good practice to first insert an old ring with a large gap in the sleeve and then the new piston ring, thus allowing the ring to seat square in the sleeve. After making this check, be sure to remove both rings. Install the new ring in the piston and check the side clearance. When the gap and the side clearance have been checked, and corrected if necessary, install the piston and ring assembly in the sleeve meshing the serrations on the outside diameter of the piston with those in the sleeve.

Installing tool (Tool No. 84692) is used to assist in the assembly of the high-speed clutch release spring. Loosely screw the tapered end of the bolt provided with this tool into the fiber body of the tool. Insert the fiber body into the bronze bushing in the rear cover. Tighten the bolt in the split fiber body sufficiently to hold the body in the bushing against the pressure of the spring, when installed.

Place the clutch release spring over the installing tool and into the annulus in the hub of the piston. Place the spacer on the spring, with the small diameter of the spacer extending inside the spring. Install the high-speed clutch thrust washer on the spacer with the lugs down. Install the clutch adapter on the thrust washer, shouldered end down. Push the adapter down, compressing the spring, and at the same time mesh the six lugs on the thrust washer with the slots in the piston lock. Hold the parts in this position and screw the knurled nut (Tool No. 84692-3) on the assembly bolt.

Lubricate the high-speed clutch disks and plates with clean engine oil and install one disk over the splines of the adapter so that the side marked "Prop. End" is towards the front. Next install one flat plate either side down. Install the other disks and plates alternately being sure that the disks are placed with the "Prop. End" towards the front. Align the lugs on the outside diameter of the plates so that they will mesh with the slots in the rim of the clutch housing, when installed. Install the housing and secure to the attaching studs in the rear cover with six washers and castellated nuts. Do not cotter the nuts at this time as it may be necessary to disassemble the high-speed clutch in order to adjust the intermediate impeller drive shaft end clearance.

Install the impeller shaft and impeller in accordance with the instructions previously given for single-speed engines.

Place the pinions and their mating bushings in their proper location in the antipropeller half of the pinion cage. Install the intermediate impeller drive shaft, meshing the teeth of the pinion gears with those of the integral gear on the shaft. Assemble the front half of the pinion cage to the rear half after checking to see that the front pinion bushings and the cage aligning pins are in place. Install and tighten the cap screws which secure the two halves of the pinion cage together, placing a new tab lock under the head of each.

Install the impeller drive gear in its bushing in the supercharger rear housing, meshing the teeth with those of the impeller shaft gear. Place the pinion cage bushing over its journal on the impeller drive gear. Install the intermediate impeller drive shaft and pinion assembly in the impeller drive gear being sure

that the teeth of the pinion gears mesh with the internal teeth of the impeller drive gear. Install the intermediate impeller drive gear on the intermediate impeller drive shaft, mating the splines with those in the rear half of the pinion cage.

Install the impeller shaft thrust ring washer, the impeller shaft thrust ring, the shim, and the retainer as previously described for single speed engines. Install the accessory drive and starter shaft.

Install the roller retainer or outer race on the intermediate impeller drive gear splines and install the intermediate impeller drive shaft thrust washer. Install the cam on the splines of the intermediate impeller drive shaft and install the cage and roller assembly in the retainer.

Install the supercharger rear housing cover and gasket temporarily, and secure with three attaching nuts and washers in each side. Remove the clearance checking plug from the rear cover. This plug is located approximately halfway between the starter and generator mounting pads. Insert the checking rod through this hole and screw into the end of the intermediate impeller drive shaft. Install the collar on the checking rod, and lock by tightening the lock screw. Screw the knurled handle on the end of the rod. Install a dial indicator on a surface gage, and adjust the position of the indicator so that the indicator spindle contacts the upper side of the collar on the checking rod. Move the intermediate impeller drive shaft up and down as far as possible by moving the checking rod, holding the knurled handle. Note the difference in the indicator readings, which is the end movement of the shaft. Insure that this end movement is greater than the minimum permissible.

If the end movement of the intermediate impeller shaft is too small, remove the rear cover and the high-speed clutch housing and grind the required amount from the conical shaped high-speed clutch spacer located at the front end of the high-speed clutch release spring. Reassemble the high-speed clutch in accordance with the instructions given previously and recheck the end movement.

When the proper clearance has been obtained, remove the checking rod and the supercharger rear housing cover. Cotter the nuts securing the high-speed clutch housing to the rear cover. Remove the roller retainer, cam, and cage assembly to permit installation of the generator drive gear. When the accessory gears have been installed, replace the roller retainer on the intermediate impeller drive gear. Install the cam and the cage and roller assembly.

Install the supercharger rear housing cover on the supercharger rear housing, using fibers to assist in installing the shafts in their respective bushings in the rear cover. Secure the rear cover to the rear housing with nuts, washers, and palnuts.

Install the two springs on the valve stem placing the stop washer between them. It is necessary that this washer have an outside diameter of 19/32 inches (15.08 mm) and a thickness of .074 to .082 inches (1.88 mm to 2.08 mm) in order to properly limit the end movement of the valve. Next install the packing washer, rubber packing, and cork packing on the valve stem. Insert the valve assembly in the valve housing being sure that the packing seats against the end of the housing. Push the valve in against the tension of the springs and install a spacer and nut on the threaded end of the valve stem. Tighten the nut against the spring tension until the valve is in the extreme out (high speed ratio) position. Slide the valve sleeve over the valve until it shoulders in the front end of the valve housing. Check to see that the three oil supply holes are not blocked. This can be done with a wire or a small light. In some assemblies, an accumulation of tolerances will allow the valve to partially block the supply holes; however, the valve will function properly if half of each hole is free. If more than half of each hole is blocked, dissamble the valve and housing and recheck the dimensions of the stop washer. Inspect the inner edge of the front land of the valve to ascertain that it has a .020 inch (0.51 mm) square groove cut around it. If it does not have the groove, and interference is encountered, it will be necessary to rework or replace the valve. Recheck the assembly for interference at the oil supply hole location.

Remove the valve sleeve, lubricate and install it in its recess in the rear cover. Install

the sleeve with the stepped end towards the rear. It may be necessary to tap the sleeve into the rear cover with a fiber. Install a new gasket on the supercharger rear cover and install the control valve and housing assembly being careful not to damage the valve or sleeve. When the valve has entered the sleeve, secure the housing to the rear cover with three washers, nuts, and palnuts. Remove the nut and spacer from the valve stem and check the operation of the valve for full travel and freedom from binding. The desired valve travel is .98 inches (24.89 mm) and under no condition should it exceed 1.00 inches (25.40 mm).

**GENERATOR AND MAGNETO DRIVE OIL SEALS** It is recommened that both sides of the sintered generator oil seal retaining ring and the shoulder on the underside of the oil seal collar be lapped to provide good mating flat surfaces. This will assist in preventing oil leakage at this location during engine operation.

To lap the sintered retaining ring, make up a plug having a low step on one end which fits the inside diameter of the ring. Install the ring on the step on the plug, and lap by hand on a lapping plate using 3M oil mix lapping compound, grade 500, or its equivalent. Lap the other side of the ring in the same manner.

To lap the shoulder on the oil seal collar, make up a plug having a diameter slightly larger than the outside diameter of the shoulder on the collar, grooved in one end to accommodate the hub of the collar. Provide several slots in the end of the plug to assist in lapping. Lap the collar on the plug by hand, using the same lapping compound as that used in lapping the sintered retaining ring.

Lap both sides of the sintered retaining ring into the shoulder on the oil seal collar, using the same lapping compound. Check these surfaces for true mating contact by bluing. Carefully clean all lapping compound from both parts.

Assemble a new neoprene diaphragm on the hub of the flanged oil seal thrust washer, and install the sintered retaining ring over the diaphragm. Place the oil seal spring over the generator drive gear in the recess in the supercharger rear housing cover. Install the oil seal assembly over the end of the generator drive gear. Take care to insure that the lobes on the outside diameter of the thrust washer are lined up with the grooves in the rear cover, and that the holes in the diaphragm are lined up with the oil seal attaching screw holes in the rear cover.

Place the generator drive oil seal collar on the splines of the installing tool (Tool No. 800232). Engage the splines on the tool with the internal splines in the generator drive gear, and drive the collar into place on the gear. See figure 190. The neoprene diaphragm

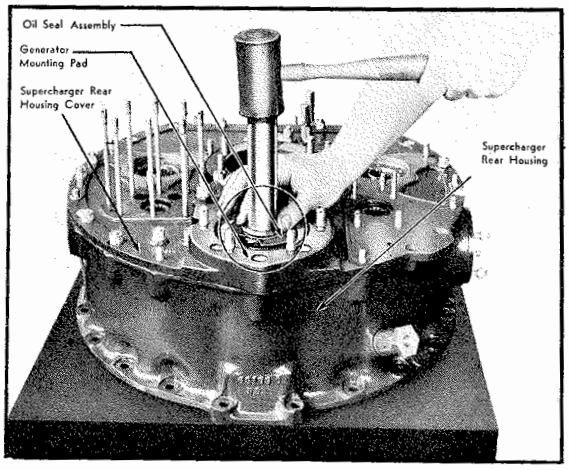



**Fig. 190. Installing Generator Drive Oil Seal Collar**

has been cut away in this figure to show the position of the lobes in the oil seal thrust washer.

Install the retainer over the oil seal assembly on the rear cover, and secure with the six attaching cap screws and shakeproof lock washers.

Lap and assemble the parts of the magneto drive oil seals in the same manner, except use installing tool, (Tool No. 800231) for driving in the magneto drive oil seal collars. See Figure 191.

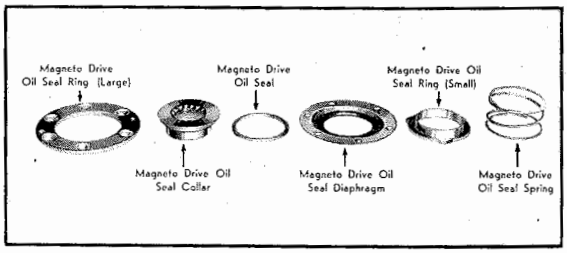

Magneto Drive Oil Seal Ring (Large)
Magneto Drive Oil Seal
Magneto Drive Oil Seal Ring (Small)
Magneto Drive Oil Seal Collar
Magneto Drive Oil Seal Diaphragm
Magneto Drive Oil Seal Spring

**Fig. 191. Magneto Oil Seal Assembly**

Install a substituting cover on the generator mounting pad.

**STARTER SHAFT SPACER, STARTER DOG, AND OIL SEAL** Install the accessory drive and starter shaft aluminum spacer in position in the starter shaft. Install the starter dog over the spacer, engaging the splines in the starter dog with the internal splines in the starter shaft.

Using a micrometer depth gage or gage (Tool No. 800258) placed on the starter mounting pad, measure the distance to the outer edge of the starter coupling jaws with the accessory drive and starter shaft and the starter dog both in the extreme forward position. See figure 192. Insure that this dimension

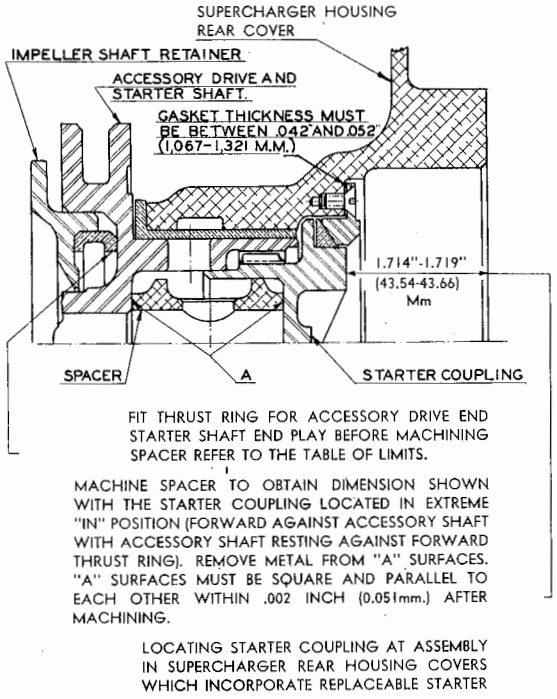

SUPERCHARGER HOUSING REAR COVER
IMPELLER SHAFT RETAINER
ACCESSORY DRIVE AND STARTER SHAFT
GASKET THICKNESS MUST BE BETWEEN .042 AND .052 (1.067-1.321 M.M.)
1.714"-1.719" (43.54-43.66) Mm
SPACER
A
STARTER COUPLING
FIT THRUST RING FOR ACCESSORY DRIVE END STARTER SHAFT END PLAY BEFORE MACHINING SPACER REFER TO THE TABLE OF LIMITS.
MACHINE SPACER TO OBTAIN DIMENSION SHOWN WITH THE STARTER COUPLING LOCATED IN EXTREME "IN" POSITION (FORWARD AGAINST ACCESSORY SHAFT WITH ACCESSORY SHAFT RESTING AGAINST FORWARD THRUST RING). REMOVE METAL FROM "A" SURFACES. "A" SURFACES MUST BE SQUARE AND PARALLEL TO EACH OTHER WITHIN .002 INCH (0.051mm.) AFTER MACHINING.
LOCATING STARTER COUPLING AT ASSEMBLY IN SUPERCHARGER REAR HOUSING COVERS WHICH INCORPORATE REPLACEABLE STARTER

**Fig. 192. Starter Coupling Location (Extreme In Position)**

measures 1.714 to 1.719 inches (43.54 to 43.66 mm). If this measurement is less than that specified, machine the required amount from the end of the spacer. If this measurement is greater than that specified, install a new spacer, machining the end if necessary to obtain the proper measurement.

Using a micrometer depth gage or gage (Tool No. 802243) placed on the starter mounting pad, measure the distance to the outer edge of the starter coupling jaws with the starter coupling in the extreme rear position. See figure 193. In order to hold the coupling

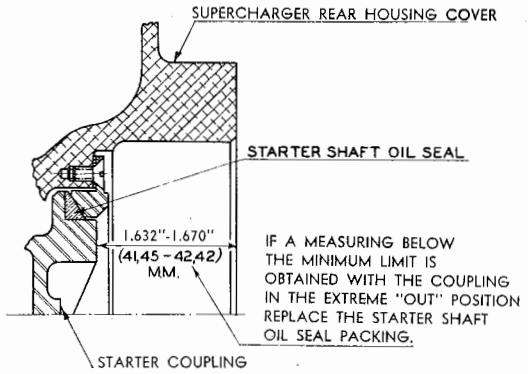
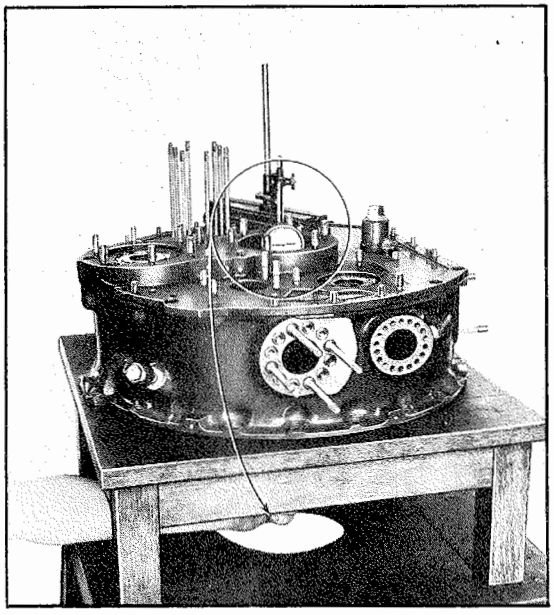

SUPERCHARGER REAR HOUSING COVER
STARTER SHAFT OIL SEAL
1.632"-1.670" (41.45-42.42) M.M.
IF A MEASURING BELOW THE MINIMUM LIMIT IS OBTAINED WITH THE COUPLING IN THE EXTREME "OUT" POSITION REPLACE THE STARTER SHAFT OIL SEAL PACKING.
STARTER COUPLING
LOCATING STARTER COUPLING AT ASSEMBLY IN SUPERCHARGER REAR HOUSING COVERS WHICH INCORPORATE REPLACEABLE STARTER COUPLINGS

**Fig. 193. Starter Coupling Location (Extreme Out Position)**

in its extreme out position while measuring, parts of timing disk (Tool No. 83517) may be used. Remove the pointer, scale, and spring



**Fg. 194. Checking Starter and Accessory Drive Shaft End Clearance**

from this assembly and use only the shaft, washer, nut, tapered plug, and expansion tool. Start the tool into the recess in the rear of the coupling, place the tapered plug in the expanding tool and tighten the washer and nut on the shaft until the tool has expanded and is tight in the coupling. Keep a constant pressure on the shaft to insure that the coupling is in the extreme rear position all during the check. See figure 194. Insure that this dimension measures 1.632 to 1.670 inches (41.45 to 42.42 mm). If the measurement is less than that specified, install a new starter shaft oil seal packing.

Install the bronze oil seal packing ring with the flat side against the starter dog. See figure 195. Install a new starter shaft oil seal retaining ring gasket and the retainer on the rear cover. Insure that the gasket used is .042 to .052 inch (1.07 to 1.32 mm) thick. Secure the retaining ring with twelve flat head screws or with fillister head screws and shakeproof lock washers, whichever is used. Secure the flathead screws after tightening by staking into the groove in the retainer.

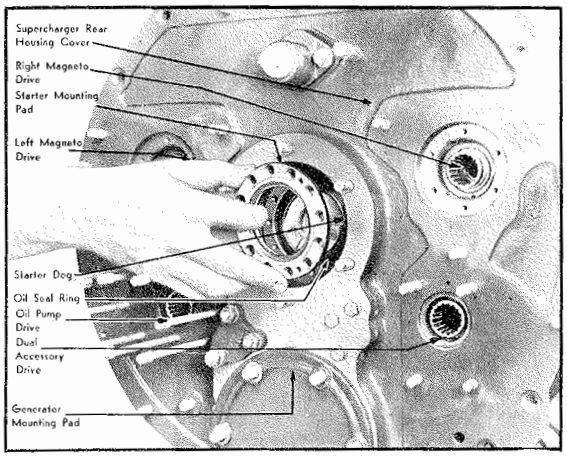



**Fig. 195. Installing Starter Shaft Oil Seal Ring**

Install a substituting cover on the starter mounting pad.

**OIL VENT CONNECTION** Install a new oil tank vent flange gasket over the oil vent connection attaching studs on the rear cover, and install the oil vent connection. Secure with flat washers, plain nuts, and palnuts. Install a pipe plug in the threads in the oil vent connection.

**SUPERCHARGER DRAIN VALVE** Assemble the supercharger drain valve body, disk and plug to the drain valve housing, using new gaskets between the body and housing and between the plug and the housing. Secure the plug with lock wire. See figure 196. The seating of the disk is satisfactory when not more than 5 cubic inches (81 cc.) of gasoline per minute pass through the valve assembly, when held in an inverted position, under a suction of 5 inches (27cm) of mercury. Lap the disk into the seat if necessary, using a light grade of lapping compound. Remove all traces of compound after the valve has been lapped, retested, and found to be satisfactory.

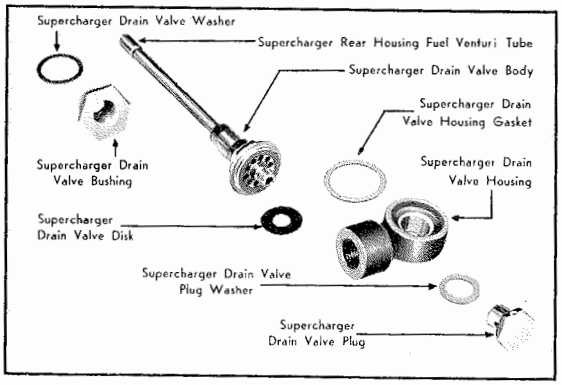

Supercharger Drain Valve Washer
Supercharger Rear Housing Fuel Venturi Tube
Supercharger Drain Valve Body
Supercharger Drain Valve Housing Gasket
Supercharger Drain Valve Bushing
Supercharger Drain Valve Housing
Supercharger Drain Valve Disk
Supercharger Drain Valve Plug Washer
Supercharger Drain Valve Plug

**Fig. 196. Supercharger Drain Valve (Exploded View)**

Tighten the supercharger drain valve bushing and washer in the supercharger rear housing, and install the steel fuel venturi tube in position in the rear housing and bushing. Install the supercharger drain valve assembly in the bushing in the rear housing, inserting the outer end of the fuel venturi tube in the drain valve body. CAUTION: Do not use excessive force when tightening this assembly into the supercharger rear housing, since that might bend the fuel venturi tube.

**DUAL ACCESSORY DRIVE** If replacement of any of the studs in the dual accessory drive housing and cover is found to be necessary, do this in accordance with instructions in the section entitled STUD REPLACEMENT, included at the beginning of this chapter.

If replacement of any of the bushings in the dual accessory drive housing and cover is found to be necessary, do this using the set of tools (Tool No. 83168). Complete instructions for replacement of any of these bushings are given on blueprint No. 83168, which is furnished with this set of tools. CAUTION: Some of the bushings in the dual accessory drive housing and cover are of the sintered type. Do not attempt to ream, scrape, or hand-burnish these bushings. Broaching the inside diameter to size is the only recommended method.

Before assembly of the dual accessory drive housing to the supercharger rear housing cover, insure that the oil pressure and drain holes in the dual accessory drive housing mounting pad on the rear cover are clear.

Clean the dual accessory drive housing mounting pad on the rear cover thoroughly, and install a new gasket in this location, over the attaching studs. Insure that the small oil hole in the gasket is punched out and indexes properly with the oil drain hole in the rear cover.

Place the dual accessory drive housing in position over the attaching studs in the rear cover, and install the nuts and washers in recesses in the housing. Tighten these nuts, using the offset box wrench (Tool No. 800684) for the two ⅝ inch (15.88 mm) hexagon nuts. Lockwire the nuts, being careful to lockwire in such a way that the wire will not interfere with the operation of the driving gears, when installed. Install and tighten the extended nut and washer on the rim of the housing at the upper right corner. Lockwire the nut. Install the two copper washers and acorn nuts on the attaching studs extending through the rim of the supercharger rear housing and rear cover. Tighten and lockwire these nuts.

Lubricate the bushings in the dual accessory drive housing thoroughly with clean engine oil. Assemble the dual accessory drive intermediate gear to the idler gear, using the proper cap screws, and wrench (Tool No. 82914). The proper cap screws for use in this location are ⅜ inch (9.53 mm) long, measured from the underside of the head to the end of the screw. Lubricate and install the dual accessory drive idler gear, the dual accessory driving gear, and the upper and lower drive gears in their respective bushings. Insure that all gears are properly meshed. See figure 197.

Install a new gasket over the attaching studs on the rim of the dual accessory drive housing. Lubricate the bushings in the dual accessory drive housing cover, and install the cover on the housing. Install and tighten two washers and 7/16 inch (11.11 mm) hexagonal head extended nuts on the upper rim of the cover. Lockwire the nuts. Install new gaskets on the accessory drive mounting pads. Install the upper and lower accessory drive substituting covers, and secure with flat washers, plain nuts, and palnuts.

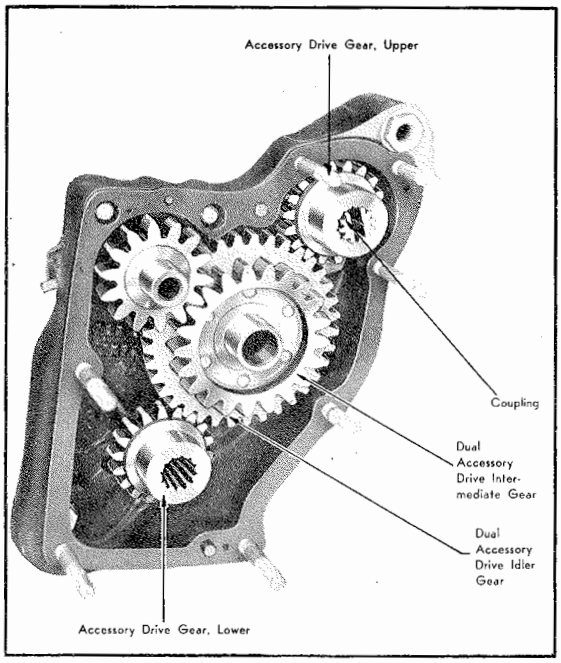



**Fig. 197. Dual Accessory Drive Gears**

**OIL PUMP** Install the oil pump drive gear shaft in the proper hole in the oil pump front end plate, and install the oil pump coupling gear, washer, and nut on the end of the shaft. Tighten the nut while holding the coupling gear using wrench (Tool No. 82676).

Tighten all oil passage plugs in the oil pump body, after insuring that the passages are clear. Install the oil suction pump idler gear shaft and the suction pump idler gear in position in the recess in the oil pump body. Install a new gasket on the front end of the oil pump body. Place the oil pump end plate in position on the gasket, meshing the oil

suction pump drive gear with the idler gear and inserting the end of the idler gear shaft in the hole provided for it in the front end plate. Install a new gasket over the oil pump attaching studs on the rear cover. Place the oil pump drive gear spring in the plug in the oil pump drive gear. Install the oil pump body and front end plate over the attaching studs on the rear cover, engaging the splines on the coupling gear with the internal splines in the oil pump drive gear. Insure that the oil pump drive gear spring is seating properly on the shoulder on the oil pump drive coupling nut. Insure that the attaching lug on the foot of the oil pump body is installed on the stud on the rim of the rear cover.

Install the oil pressure pump drive gear in the recess in the oil pump body, over the splines in the end of the oil pump drive gear shaft. Install the mating idler gear. Lubricate all parts thoroughly. Install a new gasket and the oil pump rear cover. Secure the oil pump front end plate, oil pump body and oil pump rear cover to the supercharger rear housing cover by installing flat washers and castellated nuts on the eight attaching studs which project through the rim of the cover. Tighten the nuts to the proper torque value and secure with lock wire. Install a flat washer and the special nut on the stud on the rim of the supercharger rear housing cover, securing the lower part of the oil pump body. Tighten the nut using wrench (Tool No. 800684), and secure with lock wire.

Place a new gasket over the two oil pump studs, and install the tachometer drive gear housing. Install the tachometer drive gear oil seal ring and retainer over the front end of the tachometer drive gear shaft. Install the drive gear, oil seal ring, and retainer in the housing, engaging the splines on the shaft with the internal splines in the oil pressure pump drive gear. Place the mechanical and electric tachometer drive gears in position in the housing, meshing these gears with the drive gear. Install oil seal rings over these two drive gear rear extensions, and install the two retainers. Lubricate these parts thoroughly.

Install a new gasket on the tachometer drive gear housing, and install the tachometer drive gear housing cover. Install and tighten the cap screws and flat washers which attach the tachometer drive gear housing and cover to the oil pump rear cover. Secure the cap screws with lock wire.

Install new gaskets on the mechanical and electric tachometer mounting pads. Install the mechanical tachometer drive shaft housing, and secure with two flat washers, plain nuts, and palnuts. Install the protecting cap over the threads on the end of the housing. Install the electric tachometer substituting cover, and secure with four flat washers, plain nuts, and palnuts.

Install the oil pressure relief valve body in the oil pump body using wrench (Tool No. 83660). Lubricate and install the valve, spring, and adjusting screw. Place a shouldered bronze washer over the adjusting screw, and install the lock nut. Screw the oil pressure adjusting screw approximately half way in, and tighten the lock nut. Install the other shouldered bronze washer and relief valve cap on the end of the adjusting screw. Secure the cap with lock wire.

Final adjustment of the oil pressure relief valve is made during engine test after final assembly. Refer to the chapter entitled TESTING OF ENGINE.

If an oil check valve is used, install the valve with ring, spring, a new gasket, and the retainer. If the oil check valve is removed, insert an aluminum plug in the check valve body, and install a new gasket and the retainer. Lockwire the retainer.

Install new gaskets over the inlet and outlet flange attaching studs. Install the oil inlet and outlet flanges, and secure with flat washers, plain nuts, and palnuts. Tighten pipe plugs into the tapped holes in the flanges temporarily.

Install the oil temperature thermometer connection bushings in the oil pump body. Install gaskets and plugs in the bushings, and secure with lock wire.

**GUN SYNCHRONIZERS, DRIVE SHAFTS, AND SUPPORTS** If replacement of the gun synchronizer impulse generator drive shaft support bushings is found to be necessary, do

this in accordance with the following instructions:

Place the gun synchronizer impulse generator drive shaft support on the base (Tool No. 800753-4), install block (Tool No. 800753-2) and its locking pin (Tool No. 800753-3) in in the arbor (Tool No. 800753-1), place on an arbor press table and press out the bushing.

To install these bushings insert the arbor (Tool No. 800754-4) through the base (Tool No. 800754-2) and bushing support, and place the threaded nut (Tool No. 800754-3), with the bushing to be installed under it, in the other end and engage the threads. Screw the nut down until the bushing bottoms on the support.

Using the base (Tool No. 800754-2) and the support in a drill press, broach the bushings using the broach (Tool No. 800736).

Use plug gage (Tool No. 82364) for checking the size of the broached bushings. Use length gage (Tool No. 800728) for checking the distance from the support attaching flange to the end of the bushing. Use snap gage (Tool No. 800841) when a support incorporating a diagonal drain hole near the flange is used.

Assemble each gun synchronizer impulse generator, drive shaft, and support in the following manner: Coat the drive shaft and the support bushings with clean engine oil. Insert the drive shaft in the support so that the threaded end of the shaft extends through the flanged end of the support. Install the cam and nut assembly on the shaft, and tighten the nut to the specified torque value using wrench (Tool No. 82848). (Refer to the applicable Table of Limits.) Cotter the nut, bending one end of the cotter pin over the nut, and the other end flush across the end of the shaft.

Insert the plunger into the lower housing, engaging the spline in the end of the plunger with the spline in the lower part of the housing. Place a new gasket on the drilled mounting face of the housing and place the assembled drive shaft support, shaft, and cam in position on this mounting face. Turn the shaft if necessary to bring the cam in position so that it may pass through the hole in the plunger. Insure that the drilled holes in the housing, gasket, and support are aligned. Temporarily secure these parts together by inserting the three washers and cap screws and installing a nut on each cap screw.

Install the laminated shim over the three studs on the top of the lower housing over the end of the plunger and the gasket. Secure with flat washers and castellated nuts.

Screw the plunger lock into position in the upper plunger housing, insuring that the end of the lock seats properly in the notch in the plunger. Remove the inspection plug from the side of the lower plunger housing and check the clearance between the cam lobe and the roller follower on the plunger. (Refer to the applicable Table of Limits.) If this clearance is not within the specified limits, add or remove shims from the laminated shim under the upper plunger housing until the proper value is obtained. When the clearance is satisfactory, reinstall the inspection plug and gasket, and lockwire the plug. Tighten the castellated nuts on the upper plunger housing attaching studs to the proper torque value, and secure with lock wire. Install the gun control cable replacement cover on the threads on the upper housing.

Check the end movement of the gun synchronizer drive shaft by applying pressure on the nut end of the shaft and measuring the clearance between the spiral gear and the shoulder on the front bushing. (Refer to the applicable Table of Limits.) If this clearance is too small, machine metal from the bushing shoulder to obtain the proper clearance. If this clearance is too large, it will be necessary to install a new bushing. If the clearance is satisfactory, install the plug and gasket in the lower housing at the end of the shaft, and lockwire the plug.

Install each gun synchronizer impulse generator, drive shaft, and support assembly in the supercharger rear housing and cover assembly in the following manner: Remove the nuts, cap screws, and washers temporarily attaching the gun synchronizer drive shaft support to the lower plunger housing. Place a new gasket on the gun synchronizer mounting pad on the supercharger rear housing, and install the gun synchronizer assembly in the rear housing. It may be necessary to rock the assembly slightly to mesh the gears. Insure

that the attaching cap screw holes in the lower plunger housing, drive shaft support, supercharger rear housing, and gaskets are aligned. Install the three cap screws, tighten to the proper torque value, and lockwire securely.

It is necessary to time the gun synchronizer impulse generator system after the engine is installed in the airplane. Instructions for obtaining this timing are not included in this manual.

**GUN SYNCHRONIZER SUBSTITUTING COVERS** If gun synchronizer impulse generators are not used in the engine, install the gun synchronizer impulse generator substituting covers. These covers are provided with a flange which is installed on the mounting pad on the supercharger rear housing, and an extension which serves to plug the hole in the supercharger rear housing cover, located directly under the mounting pad on the rear housing. Install and tighten three cap screws and washers to secure each substituting cover to the rear housing, and lockwire the cap screws.

**CUNO OIL FILTER** If replacement of the Cuno oil filter cartridge, relief valve, or relief valve spring is found to be necessary, do this in accordance with the following instructions: Remove the two No. 10—32 hexagonal nuts at the end of the cartridge support rods, after bending down the tab locking washers. The nuts are found at the end of the cartridge opposite from the filter attaching flange, and serve to hold the cartridge in place in the head. Slide the unit cartridge assembly along the support rods away from the filter head. This releases the relief valve assembly, permitting the relief valve and relief valve spring to fall out. Manual effort should be sufficient to move the cartridge assembly along the support rods. Do not hammer or pry the cartridge in an attempt to hasten this operation.

Hold the filter head with the support rods pointing up, place the new relief valve spring in position in the filter head, and place the new relief valve in position over the spring. Install the new unit cartridge by sliding the cartridge carefully along the support rods. Guide the relief valve assembly into the filter head during the assembly of the cartridge. Use for this purpose the eraser end of a common pencil on filters which do not have a sludge tube, or a small diameter rod on filters which are equipped with a sludge tube. After assembly of the cartridge, check to insure that the relief valve slides freely in the recess in the head. Make certain that the slot in the end of the cartridge spindle engages the driving pin in the clutch hub. The assembly is correctly made when the unit cartridge seats firmly against the filter head and the threaded ends of the support rods protrude beyond the end of the cartridge to permit installation of the tab washers and nuts.

Install the two tab washers and nuts. Use new tab washers at every installation. Lock each nut by bending the tab up to a flat on the nut.

Recheck the operation of the Cuno oil filter in the Cuno test fixture after the installation of the new parts. (Refer to the chapter entitled INSPECTION OF ENGINE PARTS, under the subtitle CUNO OIL FILTER.)

Install the filter on the supercharger rear housing mounting pad, using a new gasket between the filter and the housing. Exercise care to prevent damaging the exposed filter

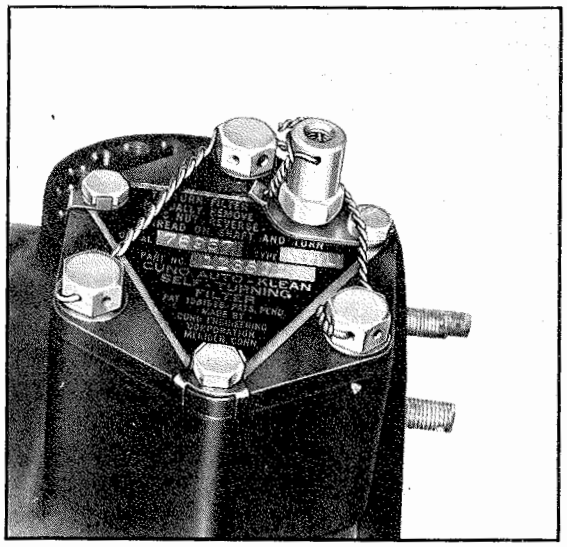


**Fig. 198. Method of Lockwiring Cuno Oil Filter**

cartridge by striking the cartridge against the sides of the filter hole. If the filter does not enter its location readily, do not attempt to force it into place. Check to determine the cause of the tight fit before attempting to install the filter again. When the installation has been correcly made, install, tighten, and lockwire the three nuts. See figure 198.

**FUEL PUMP DRIVE** If replacement of the fuel pump drive shaft support bushings is found to be necessary, do this in the following manner:

Place the fuel pump drive shaft support in the lathe fixture (Tool No. 83826) with adapter (Tool No. 83827). Bore out the bushings taking care not to remove any material from the support itself.

For installation of these bushings, place the fuel pump drive shaft support on the base (Tool No. 83835-1) with the base resting on an arbor press table. Place the bushing on the support making certain that the oil groove is located 90 deg. from the lock pin in the base (Tool No. 83835-1). Place the plug (Tool No. 83835-2) through the bushing, bushing support, and base until the larger portion shoulders against the bushing. Using the arbor press, press in the bushing until it bottoms against the support.

Place the fuel pump drive shaft support on the base (Tool No. 800031) and install in a drill press. Using a .6260 $\pm$ .0005 inch broach (Tool No. 800032) broach the bushing to size.

Use plug gage (Tool No. 84369) and flush pin gage (Tool No. 800033) for checking the size of the bushing hole and for installation respectively.

Prior to installing a new fuel pump drive shaft oil seal, check the inside diameter of the support recess and the outside diameter of the seal to insure proper fit. (Refer to the applicable Table of Limits). In the event the required fit of the seal cannot be obtained, another seal should be selected and tried for proper fit.

Install the seal in the fuel pump drive shaft support so that the leather lip on the seal faces inward. Use tool No. 801225 to press the seal into position.

Use tapered plug (Tool No. 801719) in the end of the shaft when installing the shaft in the support to prevent damaging the seal.

Coat the fuel pump drive shaft and support bushings with clean engine oil. Insert the fuel pump drive shaft in the support so that the splined end of the shaft extends through the flanged end of the support. Install the fuel pump drive shaft and support assembly in the supercharger rear housing and cover assembly, using a new gasket between the support and the rear housing. It may be necessary to turn the shaft slightly in order to mesh the gears. Install the fuel pump substituting cover gasket and cover. Install and tighten four flat washers and castellated nuts on the fuel pump attaching studs. Secure the nuts with lock wire.

# CRANKSHAFT, MASTER AND ARTICULATED RODS

Refer to the sections entitled GENERAL REPAIR PROCEDURE AND GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**CRANKSHAFT FRONT AND REAR MAIN BEARINGS** For instructions regarding the repair and handling of the crankshaft front and rear main bearings, refer to the section entitled ANTI-FRICTION BEARINGS, included at the beginning of this chapter.

**CRANKSHAFT FRONT END** Remove scratches or high spots from the outside diameter of the crankpin by light stoning, using a fine round stone. Use a rocking motion when stoning to avoid flat spots. Be particularly careful to remove burred, scratched, or galled areas that may be found on the clamping surface at the end of the crankpin. Polish with crocus cloth and light oil after stoning. Wash the entire crankshaft front end thoroughly with gasoline, and dry in an air blast.

If the crankpin is scored to such an extent that it may not be repaired by stoning, the crankpin may be ground to as much as .010 inch (0.254 mm) undersize diameter at overhaul bases properly equipped to perform this rework. This is necessary when the engine has ben operated with insufficient lubrication or with foreign material in the oil. If it is found that the crankpin requires regrinding exceeding the above limit, return the crankshaft front and rear sections to the engine manufacturer for this repair and for replacement of the crankshaft rear section with one having an undersized clamping diameter.

NOTE: **A master rod bearing having an undersize inside diameter must be used when the proper clearances cannot be maintained with a crankpin that has been ground undersize.**

If replacement of a crankshaft oil tube in the crankpin is found to be necessary, drive out the old tube using punch (Tool No. 801-317). Hold the crankshaft front end in a milling machine vise, clamping on the counterweight end, supporting the crankshaft so that the oil tube hole in the crankpin is pointing directly upwards. Insert support (Tool No. 801295) in the crankpin bore, and insert the new oil tube in the tapered hole so that it rests on the bottom of the slot in the tool. Lock the installing tool in place. Flare the tube against the tapered sides of the hole using the tapered punch (Tool No. 801325). Install the crankshaft and vise on a drill press table, locating the tube directly under the drill press spindle. Spin the tube into place using spinner Tool (Tool No. 83591). Spin the shoulder on the tube at the small end of the tapered hole using spinning tool (Tool No. 802220). Use castor oil and white lead as a lubricant during these spinning operations. Form a radius at the outer end of the tube using cutter, pilot, and holder (Tool No. 801322). Remove the tools from the crankshaft and remove the crankshaft from the vise.

Polish the rear face of the front crankshaft cheek adjacent to the crankpin fillet to obtain a finish of 13 to 15 micro-inches. It is recommended that this highly polished finish be maintained on this surface in order to prevent mutilation and excessive wear of the master rod end seal disk. Polish in accordance with the following instructions: Wrap masking tape around the crankshaft front main bearing journal. Place the crankshaft front extension in the fixture (Tool No. 801627) and clamp the fixture to a drill press table, locating the crankpin centrally under the drill press spindle.

Install the polishing tool (Tool No. 801333) in the drill press chuck. Insert four pieces of Aloxite No. 320 polishing cloth into slots equally spaced around the tool. Cut away part of the polishing cloth, if necessary, in order to prevent it from bearing on the crankpin shoulder radius. Wrap masking tape or heavy waxed paper around the crankpin in the direction of tool rotation to protect the surface of the crankpin while polishing. Castor oil applied to the crankpin may be used to hold the waxed paper in place. Lower the polishing tool into position over the crankpin, and polish the front crankcheek by turn-

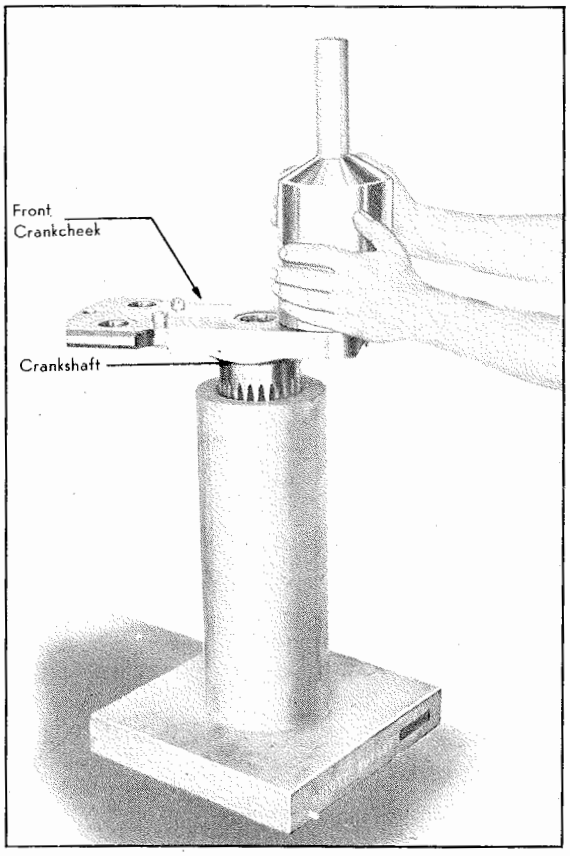



**Fig. 199. Polishing Crankshaft Front End Adjacent to Crankpin Fillet**

ing the tool at a speed of approximately 600 rpm, exerting a moderate pressure of the tool on the work. See figure 199. A worn cloth is essential for a high finish. Determine the finish obtained in polishing by comparison with the 15 micro-inch finish reference block (Tool No. 801762).

The tools required for performing this polishing operation form part of the set of tools provided under Tool No. 801850. Blueprint No. 801850, also provided with this set, shows the tools in position for polishing.

If replacement of the crankshaft front end bushings is found to be necessary, do this in the following manner: Place the base (Tool No. 83523) on an arbor press table and place the crankshaft horizontally on the base so that the bushing to be removed is located over the large hole in the base. Press out the bushing using plug (Tool No. 84809). Remove burrs from the bushing hole in the crankshaft and smooth the inside diameter of the hole using crocus cloth and gasoline. Check the inside diameter of the bushing hole and the outside diameter of the new bushing to insure that the proper fit will be obtained. (Refer to the applicable Table of Limits.)

Apply a thin coating of Lubriplate 130-A, or its equivalent, to the new bushing. Place the crankshaft on base (Tool No. 83523) on an arbor press table, and press in the new bushing using plug (Tool No. 84809) and collar (Tool No. 84811). Install the collar on the plug so that the step on the collar is against the bushing. This insures that the bushing will be installed to the proper depth.

If replacement of the crankshaft front counterweight bushings is found to be necessary, do this in the following manner: Place the base (Tool No. 83523) on an arbor press table and place the front counterweight horizontally on the base so that the bushing to be removed is located over the small pilot hole in the base. Press out the bushing using plug (Tool No. 84809), piloting the shank of the plug in the pilot hole in the base. Remove burrs from the bushing hole in the counterweight and smooth the inside diameter of the hole using crocus cloth and gasoline. Check the inside diameter of the bushing hole and the outside diameter of the new bushing to insure that the proper fit will be obtained. (Refer to the applicable Table of Limits.)

Apply a thin coating of Lubriplate 130-A to the new bushing. Attach the adapter (Tool No. 84810) to the stop plate (Tool No. 83445) by means of two No. 10—32 flat head screws. Insert the stop plate into the slot in the counterweight so that the edge of the adapter contacts the flat side of the counterweight. Tighten the two wedges into the slots provided in the stop plate so that the side of the stop plate is contacting the side of the counterweight in which the new bushing is to be installed. Place the counterweight on base (Tool No. 83523) on an arbor press table, and press in the new bushing using plug (Tool No. 84809) until the bushing is bottomed on the stop plate. The bushing is then installed to its proper depth.

Before assembling the front counterweight to the crankshaft front end, coat the inside diameter of the counterweight bushings and the crankshaft front end bushings thoroughly with Lubriplate 130-A. Install the front counterweight on the crankshaft front end so that the front crankshaft cheek extends into the slot in the counterweight. CAUTION: Insure that the end of the counterweight which is marked "PROPELLER END" is facing the front of the crankshaft.

Thoroughly coat the counterweight pins with Lubriplate 130-A. Hold the counterweight in position and install the counterweight pins. Install the front counterweight stop plate on the front face of the crankshaft cheek, and secure with two bolts and nuts. Tighten the nuts and secure with cotter pins.

Coat the crankpin front plug with Lubriplate 130-A and install in the crankpin. Insure that the hole in the plug is aligned with the tapped hole in the crankshaft. Install a new tab lock and the crankpin front plug locking cap screw. Tighten the cap screw and bend up the tab lock to secure it.

Install the crankcase front end in the assembly and disassembly fixture (Tool No. 800710, mounted on floor stand, Tool No. 800711). Tighten the two clamps on the fixture to hold the crankshaft firmly in the fixture, with the counterweight in the downward position.

Coat the breather tube rear support or substituting plug, whichever is used, with Lubriplate 130-A, or its equivalent, and install in the crankshaft cheek. Insure that the hole in the plug is aligned with the tapped hole in the crankshaft. Install a new tab lock and the locking cap screw. Tighten the cap screw and bend up the tab lock to secure it.

**CRANKSHAFT REAR END** Polish the front face of the crankshaft rear adjacent to the crankpin hole to obtain a finish of 13 to 15 micro-inches. It is recommended that this highly polished finish be maintained on this surface in order to prevent mutilation and excessive wear of the master rod end seal spacer. See figure 200 for a

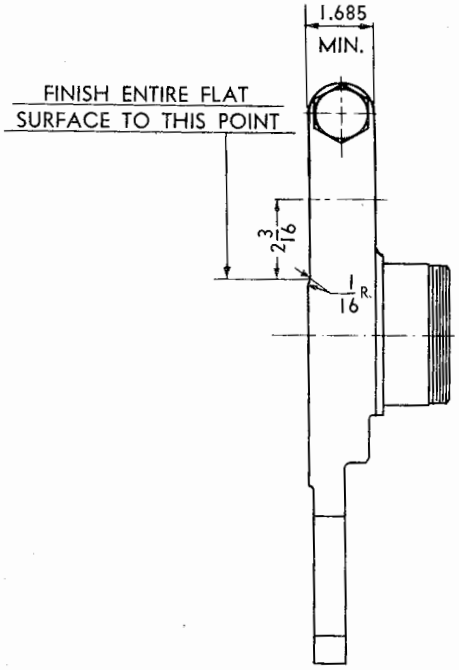



**Fig. 200. Polished Area of Front Face of Crankshaft Rear**

sketch showing the area to be polished. Prepare the crankshaft rear end for polishing in the following manner: Bolt the holding plate (Tool No. 801846-1) vertically and firmly to a solid support. Attach the fixture (Tool No. 801846-2) to the holding plate. Spread the clamping joint of the crankshaft rear using the spreader plug (Tool No. 84765-1), plate (Tool No. 84765-2) and screw (Tool No. 84699), in order to permit installation of the crankshaft rear on the fixture. Install the crankshaft rear on the plug on the fixture with the rear end toward the fixture, so that approximately 1/32 inch (0.80 mm) clearance exists between the crankshaft rear extension and the fixture. Remove the spreading tools from the crankshaft rear and install the clamping cap screw. Clamp the crankshaft rear to the fixture by tightening the cap screw to the proper stretch, using wrench (Tool No. 80309) and extension (Tool No. 80198). (Refer to the applicable Table of Limits.) Remove the fixture and crankshaft rear half from the holding plate.

Polish the front face of the crankshaft rear adjacent to the crankpin hole in the following manner: Wrap a strip of crocus cloth around a parallel bar of convenient size. Polish the part, using kerosene or Varsol as a lubricant. See figure 201. Determine the finish obtained

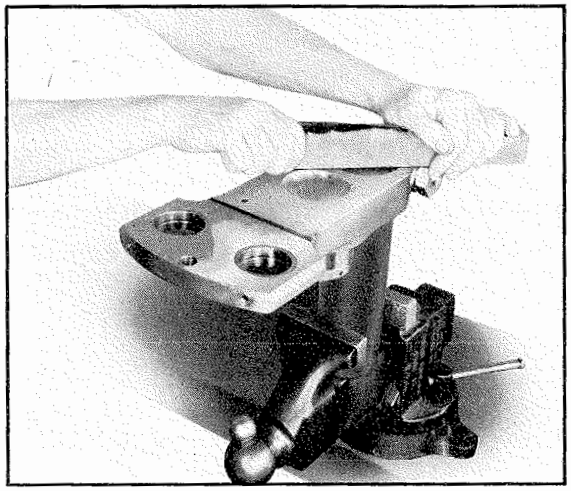


**Fig. 201. Polishing Crankshaft Rear End Adjacent to Crankpin Hole**

by comparison with the 15 micro-inch finish reference block (Tool No. 801762). Check the polished surface for squareness using the bluing gage (Tool No. 801846-9) and bushing (Tool No. 801846-4). Measure the width of the crankshaft rear adjacent to the crankpin hole to insure that it is greater than the minimum permissible width of 1.685 inches (42.80 mm). See figure 202.

The tools required for performing this

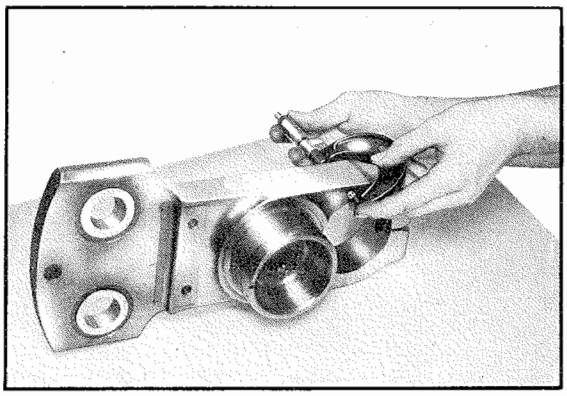


**Fig. 202. Measuring Width of Crankshaft Rear**

polishing operation form part of the set of tools provided under Tool No. 801850. Blueprint No. 801850, also provided with this set, shows the tools in position for polishing.

Press out the bushing bearing in the crankshaft rear section just far enough to clear the oil passages in the crankcheek extension. Use plug (Tool No. 83525) and collar (Tool No. 800512). It is advisable to leave the bushing bearing partly in the crankcheek extension in order to preserve the proper alignment of the oil passages. Clean the lubrication holes thoroughly. Press the bushing back into place.

If replacement of the crankshaft rear end bushing bearings is found to be necessary, remove the bearings in the same manner as previously described for the crankshaft front end bushings, except use plug (Tool No. 83525) and collar (Tool No. 800512). Remove burrs from the bearing hole in the crankshaft and smooth the inside diameter of the hole using crocus cloth and gasoline. Check the inside diameter of the bearing hole and the outside diameter of the new bearing to insure that the proper fit will be obtained. (Refer to the applicable Table of Limits.)

Place the crankshaft on base (Tool No. 83523) on an arbor press table, and press in the new bearing using plug (Tool No. 83525) and collar (Tool No. 800512). Install the collar on the plug so that the end of the collar marked "THIS END FOR INSTALLING" is inserted in the bearing. This insures that the bearing will be installed to the proper depth. CAUTION: Do not lubricate these bearings with Lubriplate.

If replacement of the crankshaft rear counterweight bushings is found to be necessary, remove the bushings in the same manner as previously described for the crankshaft front counterweight bushings, except use plug (Tool No. 83525). Remove burrs from the bushing hole in the counterweight and smooth the inside diameter of the hole using crocus cloth and gasoline. Check the inside diameter of the bushing hole and the outside diameter of the new bushing to insure that the proper fit will be obtained. (Refer to the applicable Table of Limits.)

Press in the new bushing in the same manner as previously described for crankshaft front counterweight bushings, except do not use adapter (Tool No. 84810) in connection with the stop plate when installing the rear counterweight bushings, and use plug (Tool No. 83525).

Before assembling the rear counterweight to the crankshaft rear, coat the inside diameter of the counterweight bushings and the floating crankshaft rear end bushings thoroughly with Lubriplate 130-A, or its equivalent. Install the rear end bushings in the bronze bearings in the crankshaft rear. Install the rear counterweight on the crankshaft rear end so that the rear crankshaft cheek extends into the slot in the counterweight. CAUTION: Insure that the end of the counterweight which is marked "ANTIPROPELLER END" is facing toward the rear of the crankshaft.

Thoroughly coat the counterweight pins with Lubriplate 130-A, or its equivalent. Hold the counterweight in position and install the counterweight pins. Install the rear counterweight stop plate on the rear face of the crankshaft rear, and secure with two bolts and nuts. Tighten the nuts and secure with cotter pins.

Install the starter shaft coupling in the crankshaft rear, engaging the external splines on the coupling with the internal splines in the crankshaft rear extension.

**MASTER ROD** If replacement of the master rod bearing is found to be necessary, do this in accordance with the following instructions:

Place the master rod on the base of the

fixture (Tool No. 84815) so that the crankpin bore fits over the large boss in the center of the base and No. 6 knuckle pin hole fits over the aligning pin. The bearing splines should be facing upward. Install the top section of Tool No. 84815 and secure it in position with the nut provided for that purpose. The assembly is placed on a drill press table and the guiding hole in the tool is lined up with the reamer (Tool No. 84819) in the spindle. Ream the bearing. This operation produces a curved groove on the surface of the bearing. Replace the rod on the fixture so that No. 5 knuckle pin hole fits over the aligning pin. This changes the relative position of the bearing to the reamer. Install the top section of the tool and secure it in position. Align the guiding hole and reamer, and ream the bearing as before. Remove the master rod from the tool and install it with grooves up in a vise between brass jaws. The section of the bearing between the two grooves must be removed before the remainder of the bearing can be taken out. To remove this section, insert the chisel between the two splines above the thin section of each groove and tap the chisel with a hammer until the shoulder of the bearing is split. Repeat this process on the shoulder above the other groove. Using a brass drift and a hammer, tap down on the splines between the two cuts until the section bends and curls inside the master rod bore. Continue tapping this bearing section through the master rod bore until a strip is removed from the bearing. The bearing may then be removed by hand. If it sticks, tap it lightly with the brass drift and hammer. Extreme care should be taken in using the hammer and chisel so as not to damage the master rod.

Clean the master rod bore with crocus cloth and kerosene and polish with a cloth wheel.

If the master rod bore is marred by scores, scratches or severe chafing, it should be returned to the factory to be reworked.

When installing the new bearing, the master rod should be heated up to approximately 400 deg. F. (205 deg. C.) in an oil bath for a period of at least 30 minutes. The master rod should then be placed in an arbor press and the bearing dropped in place. The oil holes in the bearing and rod must line up within 1/16 inch (1.58 mm). The flanged end should be located at the front side of the rod. Insert the arbor press plug (Tool No. 84400) in the bearing and apply a pressure on the bearing until the rod has cooled sufficiently to hold the bearing. Use adapter (Tool No. 84401) for this operation. Provision has been made so that while using these tools, correct alignment of the splines on the bearing will be obtained, in order that the knuckle pin locking plate will be properly located, when installed.

Finish bore the master rod bearing in accordance with the following instructions: Install the two locating pins in the knuckle pin holes closest to the shank of the master rod. Install knuckle pins in the remaining six holes. If this procedure is followed, the bearing surface will not be distorted when the articulated rods and knuckle pins are finally assembled on the master rod.

Bore out the bearing to the dimension which will provide the correct clearance. (Refer to the applicable Table of Limits). Use fixture and tools provided under Tool No. 83432 for finish boring. Instructions for use of these tools are furnished with the set of tools.

To remove the piston pin bushing, insert the small end of plug (Tool No. 83410-1) into the piston pin bushing. Place base (Tool No. 83409) on an arbor press table and insert collar (Tool No. 83410-2) in the base. Support the rod over the collar. Press out the old bushing. Remove the plug and the rod. Clean up the rod bore and remove all burrs.

To install the new piston pin bushing, place the bushing on the small end of plug (Tool No. 83410-1) and screw cap (Tool No. 83579) on the plug. Lubricate the outside diameter of the new bushing with castor oil. Place the piston pin end of the rod over collar (Tool No. 83410-2) and insert the large end of the plug through the bore so that it extends into the collar. Locate the split in the piston pin bushing in the extreme end of the rod at an angle of 45 deg. to the center line of the rod journal. Using an arbor press, press down on the cap on the top of the plug until the press-in plug bottoms against the collar. Remove the plug and collar.

After a new piston pin bushing has been installed, the new bushing should be broached to provide a satisfactory surface contact between the bushing and bushing bore in the rod. This is accomplished by pressing a proper size burnishing broach through the bushing by means of an arbor or hydraulic press. Burnishing broaches have a series of steps or buttons, each one of the first 12 steps or buttons .001 inch larger in diameter than the preceding one. Selective fit broaches are available under Tools No. 801230-1, -2, -3, and -4. To properly broach newly installed piston pin bushings, proceed as follows: Try each of the above mentioned broaches in the bushing by hand and select one in which from four to seven steps or buttons enter the bushing. If less than four steps or buttons enter the bushing, the broach is too large. If more than seven steps or buttons enter the bushing, the broach is too small. Install the selected broach in an arbor or hydraulic press. Place collar (Tool No. 83410-5) in base (Tool No. 83409) and set the base with collar on the press table. Locate the rod with the new piston pin bushing over the collar in the base and broach the piston pin bushing using from 500 to 600 lb. per square inch (35.2 to 42.2 kg./sq.cm.) pressure to force the broaching tool through the bushing.

To spin piston pin bushings, insert spinning tool (Tool No. 83345) in a drill press spindle. Support the piston pin end of the rod on plug (Tool No. 83413) in base (Tool No. 83409) and spin over the end of the piston pin bushing. Invert the rod and spin over the other end of the bushing. The ends of the bushing should be spun over until they bottom against the chamfer machined at each end of the bushing in the rod.

To face the ends of piston pin bushings, insert plug (Tool No. 83413) in base (Tool No. 83409) and locate the piston pin bushing end of the rod on the plug. Install counterbore holder (Tool No. 81362), counterbore (Tool No. 83208) and pilot and nut (Tool No. 83421) in a drill press spindle. Lower the drill spindle to locate the counterbore pilot in the plug hole and face off one end of the bushing. Invert the rod and face off the other end. The ends of the bushing should be faced flush with the rod, and should run true with the bore within .002 inch (0.051 mm) full indicator reading.

Finish-bore the piston pin bushings to size as follows: Check the diameter of the piston pin at the piston bushing location. (Refer to Table of Limits for special clearance.) Adjust the cutting tool in the boring bar using the .600 inch (15.2 mm) constant shoe with the micrometer. Using boring fixture (Tool No. 83432) finish bore the bushings to size. Form a .015 inch (0.381 mm) radius at both ends of the bushing. Remove burrs, wash in gasoline and wipe off clean. Check the finished size of the bushing bores.

Scratches or galled areas in knuckle pin holes in the master rod flanges should be removed with crocus cloth. If the scratches or galled areas are deep and not easily removed, it is recommended that the rods be returned to the factory for inspection.

Polish the rear face of the master rod large end to obtain a finish of 13 to 15 micro-inches. It is recommended that this highly polished finish be maintained on this surface in order to prevent mutilation and excessive wear of the master rod end seal spacer. Polish in accordance with the following instructions: Bolt the fixture (Tool No. 801628) to a drill press table approximately ½ inch (13 mm) out of line with the drill press spindle. Using belt dressing or cement, attach a piece of Aloxite No. 320 polishing cloth, or its equivalent, to the plane surface of the polishing tool (Tool No. 801547). Use for this purpose a circular piece of polishing cloth approximately the same diameter as the plane surface of the polishing tool. Chuck the polishing tool in the drill press, and place the master rod on the fixture (Tool No. 801628) with the rear face of the large end up. Polish the rear end of the master rod by turning the tool at a speed of approximately 600 rpm, exerting a moderate pressure of the tool on the work. Oscillate the master rod in the fixture while polishing holding the small end of the rod. See figure 203. A worn cloth is essential for a high finish. Determine the finish obtained in polishing by comparison with the 15 micro-inch finish reference block (Tool No. 801762).

The tools required for performing this

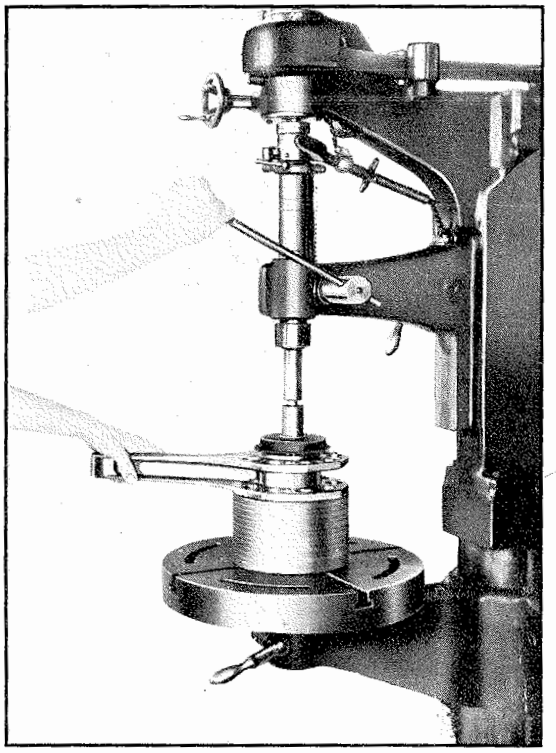


Fig. 203. Polishing Master Rod Rear End

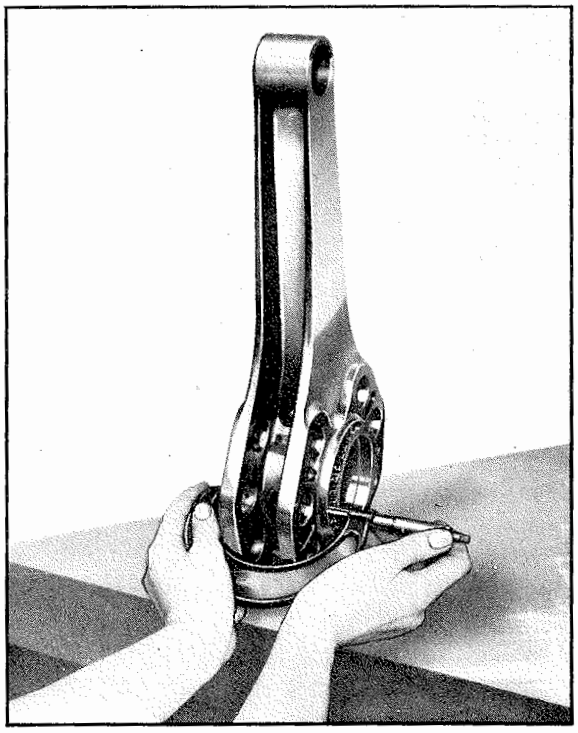


Fig. 204. Measuring Width of Master Rod Hub

polishing operation form part of the set of tools provided under Tool No. 801850. Blueprint No. 801850, also provided with this set, shows the tools in position for polishing.

Measure the width of the master rod hub using a micrometer, inserting the micrometer spindle between two of the splines on the master rod bearing at the front end of the hub. See figure 204. Insure that the measured width is greater than the minimum permissible width of 3.145 inches (79.88 mm). Subtract the measured width of the master rod hub from the original width of 3.167 inches (80.44 mm), and record this figure for future use in determining the proper oversize master rod end seal spacer to be used. This figure represents the amount of material removed from the rear face of the master rod hub. See figure 205.

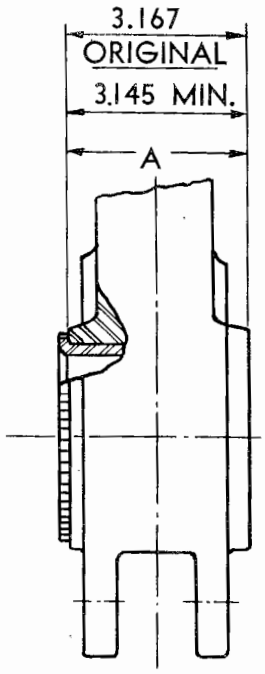



Fig. 205. Master Rod Original and Minimum Width

**ARTICULATED RODS** If replacement of a piston pin bushing is found to be necessary, do this in the same manner as previously described for master rods. If replacement of a knuckle pin bushing is found to be necessary, do this in accordance with the following instructions:

Remove the knuckle pin bushings following the procedure as outlined for removal of piston pin bushings, except use base (Tool No. 83409), collar (Tool No. 83412-2) and plug (Tool No. 83412-1).

Install new knuckle pin bushings in the same manner as described for installing piston pin bushings, except use collar (Tool No. 83412-2), screw cap (Tool No. 83579) and plug (Tool No. 83412-1).

Broach newly installed knuckle pin bushings following the same procedure as outlined for broaching piston pin bushings except use base (Tool No. 83409), collar (Tool No. 83412-4) and burnishing broach (Tool No. 83420).

Knuckle pin bushings are spun in the same manner as described for piston pin bushings except use plug (Tool No. 83415), base (Tool No. 83409) and spinning tool (Tool No. 83373).

Face the knuckle pin bushings in the same manner as facing piston pin bushings, except use plug (Tool No. 83417). Face the bushing on one side to within .005 inch (0.125 mm) of the face of the rod. Turn the rod over and face the other end of the bushing in the same manner.

Finish-bore knuckle pin bushings in the same manner as finish-boring piston pin bushings with the exception that an added .0005 inch (0.013 mm) must be made for lead plating bushings. Following the boring operation, form a .015 inch (0.051 mm) radius at both ends of the bushing. Wash the assembly thoroughly and check the finished size of the bushing bores.

Check the alignment of the bushing bores as described in the INSPECTION Chapter.

Lead plate the bushings if desired as described early in this chapter.

**ASSEMBLY OF MASTER ROD AND ARTICULATED RODS**

Before assembling the articulated rods to the master rod, coat the knuckle pin holes in the master rod with Lubriplate 130-A, or its equivalent, and coat the knuckle pin bushing in the articulated rods with clean engine oil.

Articulated rods and knuckle pins are marked with the number of the cylinder in which they were originally installed. These parts must be installed in their original position. If new parts are used, identify them for proper position.

The knuckle pins must be assembled in the master rod so that the side of the step in the small end of each knuckle pin will mate with the squared end of the lugs in the knuckle pin locking plate, upon installation of the locking plate. Provision is made in the knuckle pin assembly and disassembly fixture (Tool No. 83913-1) to properly locate the knuckle pins in this manner. Another means must be used to properly locate the knuckle pins when the fixture (Tool No. 800260) is used, and this will be described in a following paragraph. (Tool No. 83913 is a set of tools, and includes all tools necessary for removal and installation of knuckle pins. Tool No. 800260 is a fixture, used in connection with wedges, Tool No. 800282, and plugs, Tool No. 800283, for performing the same operations.)

To install knuckle pins using the set of tools (Tool No. 83913), place the master rod on the fixture (Tool No. 83913-1) with the bearing flanged end down and with the spring-loaded locating pin on the fixture projecting into a knuckle pin hole. The two locating blocks which bear on the master rod hub, one on each side of the rod, locate the master rod correctly in the lateral direction. Clamp the master rod in this position. Place the fixture and rod on the arbor press table and locate the spring-loaded pin on the fixture directly under the arbor. Push down the locating pin on the fixture and install the proper articulated rod in position over the locating pin. Place a knuckle pin in position in the master rod so that the step on the end of the knuckle pin mates with the step in the locating pin. Insert the two wedges (Tool No. 83913-19) between the flanges of the master rod on each side of the articulated rod. Press in the knuckle pin using the installing plug (Tool No. 83913-21) under the arbor, fitting the boss on the plug in the bore in the end of the knuckle pin. When the locating pin bottoms in the fixture, the small end of the knuckle pin will be within the required limits of flush to .002 inch (0.051 mm) above flush with the front

face of the master rod front flange.

Install all knuckle pins in this manner.

To install knuckle pins using the fixture (Tool No. 800260), first locate the knuckle pins in the master rod so that the step in the knuckle pins will mate properly with the lugs in the knuckle pin locking plate. To do this, install the knuckle pin locking plate temporarily on the front of the master rod, engaging the splines on the inside diameter of the locking plate with the splines of the master rod bearing flange. Install one articulated rod and its knuckle pin in the proper position in the master rod by hand. Place a metal rule approximately ⅝ inch (16 mm) wide over the squared end of the lug on the locking plate so that the end of the rule contacts the end of the knuckle pin. Turn the knuckle pin until the side of the step in the end of the knuckle pin is flat against the rule when the rule is flat against the end of the lug on the locking plate. Tap the knuckle pin into the master rod using a fiber mallet just far enough so that the pin is tight in the rod. Repeat this procedure for each of the other knuckle pins and articulated rods. When all of the knuckle pins have been installed in this manner, remove the knuckle pin locking plate.

Place the master and articulated rod and knuckle pin assembly on the fixture (Tool No. 800260) on an arbor press table, with the stepped end of the knuckle pins down. Insert two wedges (Tool No. 800282) between the flanges of the master rod on each side of one articulated rod. Press the knuckle pin into the master rod until the front face of the pin bottoms on the fixture. Insure that the knuckle pin being pressed in is not over the hole in the base. Installing plug (Tool No. 800283-1) is used under the arbor for this pressing-in operation. See figure 206.

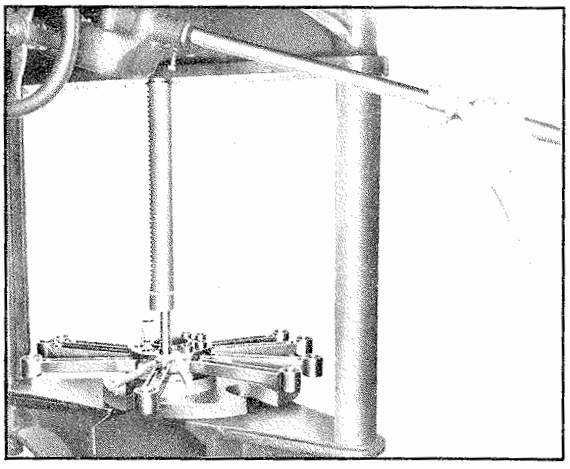


Fig. 206. Pressing In Knuckle Pins

Press in all knuckle pins in this manner.

Do not under any circumstances drive knuckle pins into or out of master rods using a drift and hammer. Hammer blows on the hardened surface of a knuckle pin during assembly might start small cracks, which, under operating conditions, could enlarge to cause failure of the knuckle pin.

Complete the assembly of the master rod in the following manner: Install the knuckle pin locking plate in position on the front end of the master rod, engaging the splines on the inside diameter of the locking plate with the splines on the master rod bearing flange. Check to insure that the squared ends of the lugs on the locking plate mate with the flat side of the step on the knuckle pins. Install new tab locks and the knuckle pin locking cap screws. Tighten the lock screws and bend up the tab locks to secure them. See figure 207.

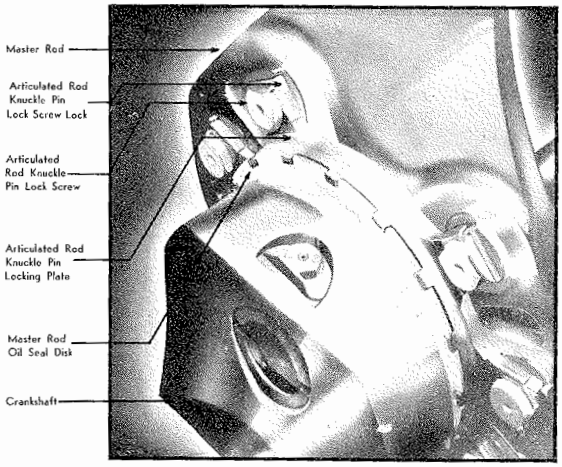

Master Rod
Articulated Rod Knuckle Pin Lock Screw Lock
Articulated Rod Knuckle Pin Lock Screw
Articulated Rod Knuckle Pin Locking Plate
Master Rod Oil Seal Disk
Crankshaft

Fig. 207. Method of Locking Knuckle Pins

Place the master rod end seal spring in position in the master rod end seal disk, and place the disk and spring in position in the locking plate, engaging the lugs on the disk with those on the locking plate.

It is necessary to install the crankshaft rear

temporarily on the crankpin to determine the proper oversize master rod end seal spacer to be used. Install the crankshaft rear spreader plug (Tool No. 84765-1) in the unthreaded end of the cap screw hole, and install the plate (Tool No. 84765-2) in the slot in the plug so that the plate contacts the side of the clamp joint. Tighten the screw (Tool No. 84699) in the threaded end of the cap screw hole, forcing the plate against the side of the clamp joint and spreading the crankshaft rear. Do not spread the crankshaft rear any more than is necessary to permit installation on the crankpin.

Assemble the crankshaft rear on the crankpin, with the crankshaft front end held in the assembly and disassembly fixture, so that the overall measurement from the front main bearing shoulder to the rear main bearing shoulder is 7.062 inches (179.37 mm). See figure 208. Loosen the spreader screw, allowing the crankshaft rear to clamp onto the crankpin. Measure the distance between the shoulder at the crankpin fillet and the front face of the crankshaft rear using an inside micrometer. See figure 209. From this measurement, subtract the original measurement between these surfaces, which is 3.562 inches (90.47 mm) when new parts are used. This figure represents the amount of material removed from the crankshaft surfaces. Add to this figure the amount of material found to be removed from the master rod, determined previously. The sum of these figures is the oversize spacer required for use when the crankshaft is assembled. Master rod end seal spacers are provided in oversize thick-

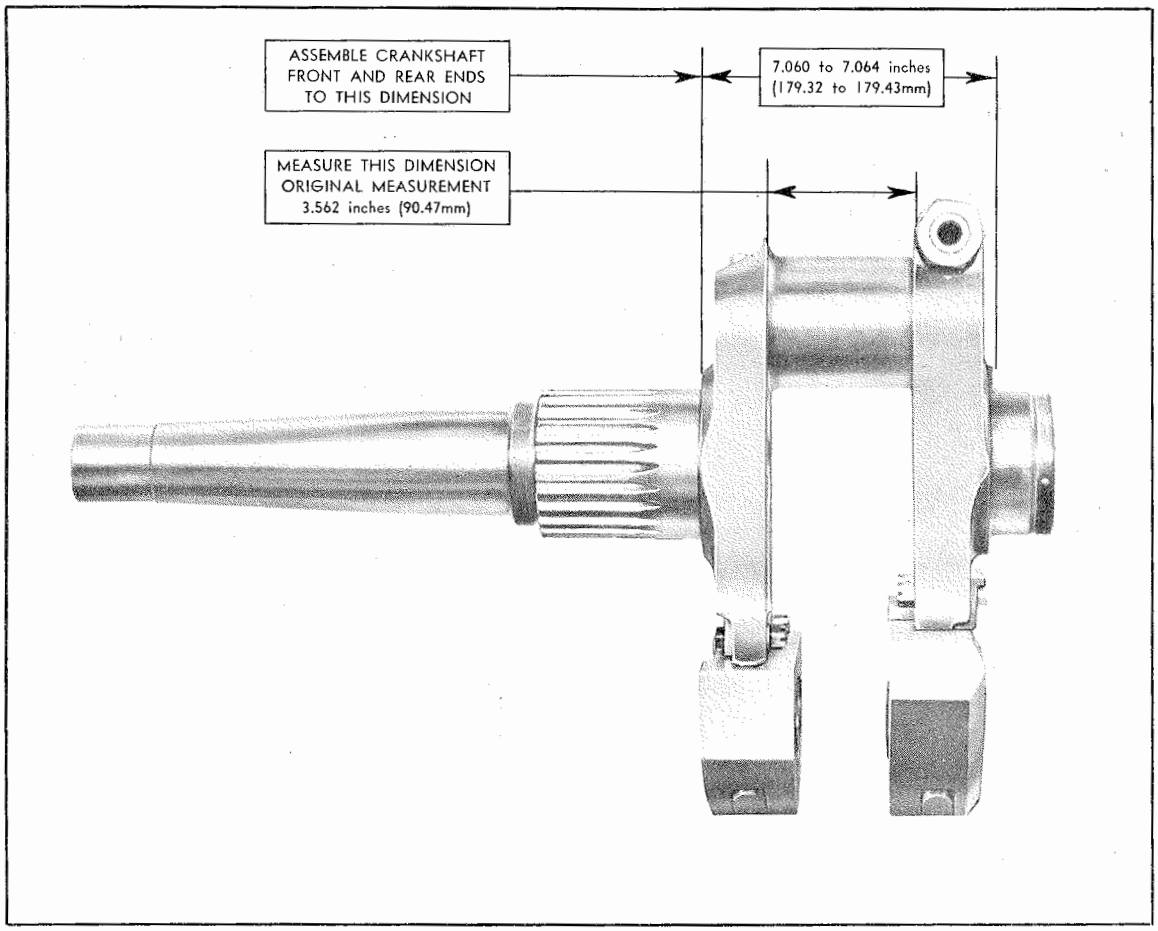

ASSEMBLE CRANKSHAFT FRONT AND REAR ENDS TO THIS DIMENSION
7.060 to 7.064 inches (179.32 to 179.43mm)
MEASURE THIS DIMENSION ORIGINAL MEASUREMENT 3.562 inches (90.47mm)

**Fig. 208. Crankshaft Assembly Dimensions**

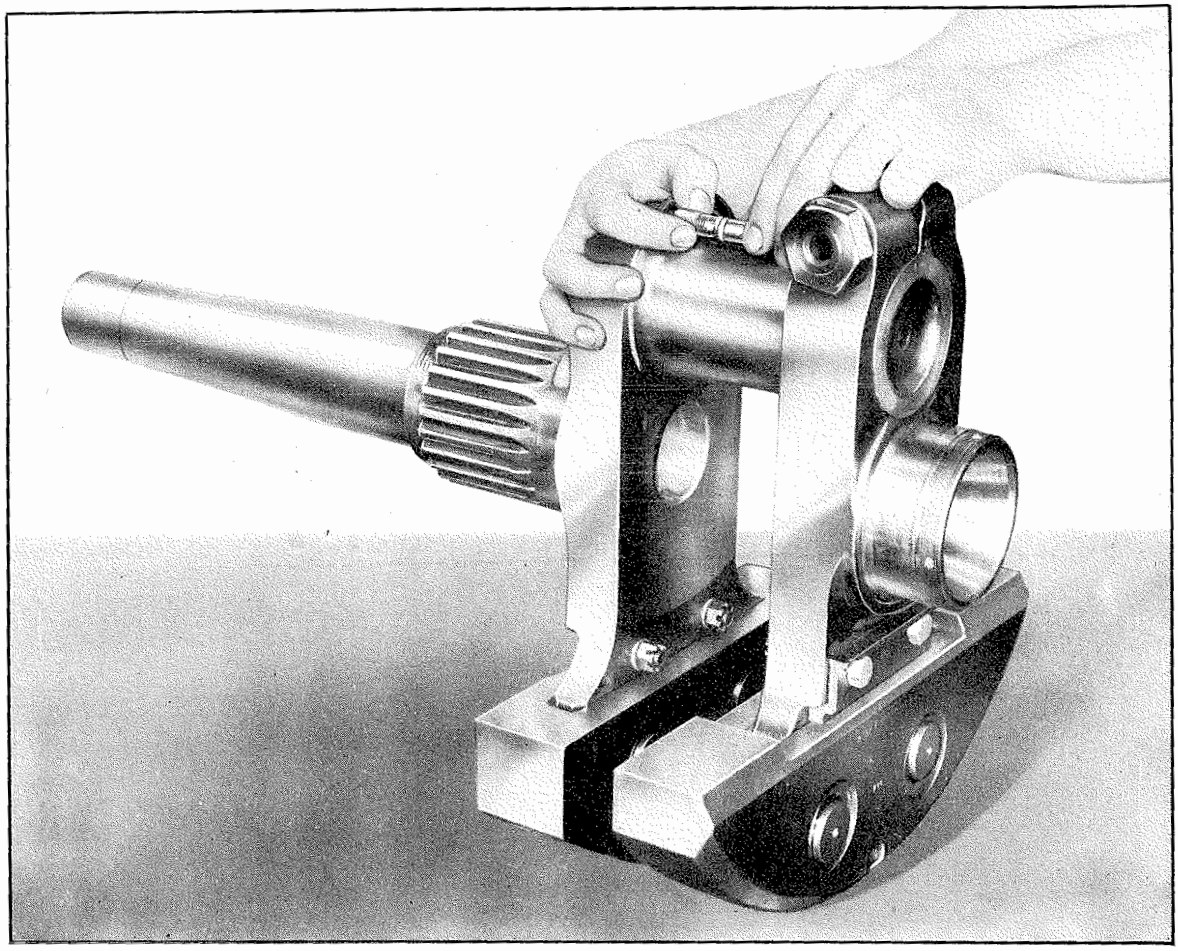


**Fig. 209. Measuring Distances From Crankpin Fillet to Front Face of Crankshaft Rear**

ness of .005 inch (0.127 mm), .010 inch (0.254 mm), .020 inch (0.508 mm), .030 inch (0.762 mm), .040 inch (1.016 mm), and .050 inch (1.270 mm).

**EXAMPLE**

| | | |
|---|---|---|
| Measured distance between crankpin shoulder and crankshaft rear | 3.575 inches (90.80 mm) | |
| Subtract original measurement between crankpin shoulder and crankshaft rear | 3.562 inches (90.47 mm) | |
| (A) Material removed from crankshaft surfaces | | 0.013 inch (0.33 mm) |
| Original width of master rod hub | 3.167 inches (80.44 mm) | |
| Subtract measured width of master rod hub | 3.160 inches (80.26 mm) | |
| (B) Material removed from master rod hub | | 0.007 inch (0.18 mm) |
| Oversize spacer required = (A) + (B) | | 0.020 inch (0.51 mm) |

When it has been determined which oversize master rod end seal spacer is required, remove the crankshaft rear from the crankshaft front end.

**CRANKSHAFT ASSEMBLY** Wash the crankpin thoroughly with gasoline, dry in an air blast, and lubricate freely with clean engine oil. Lubricate the

inside diameter of the master rod bearing with clean engine oil and install the master rod oil seal disk spring and disk. See figure 210. Hold the master rod in a vertical position

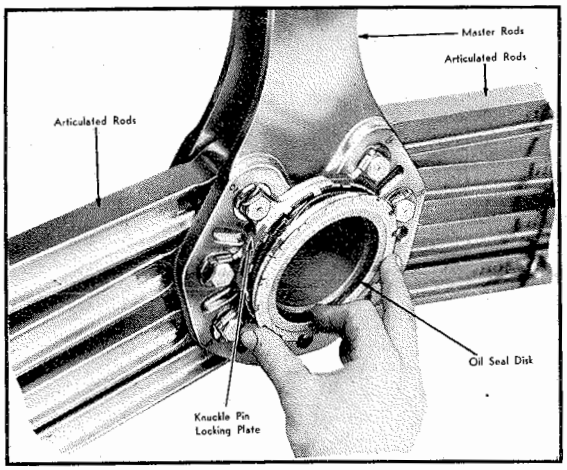



**Fig. 210. Installing Master Rod Oil Seal Disk**

and group four articulated rods on both sides of the master rod together, holding each group of rods together with a heavy rubber band. With the crankshaft front end clamped in the crankshaft assembly and disassembly fixture, install the master and articulated rod and end seal assembly on the crankpin. See figure 211. Install the proper oversize spacer

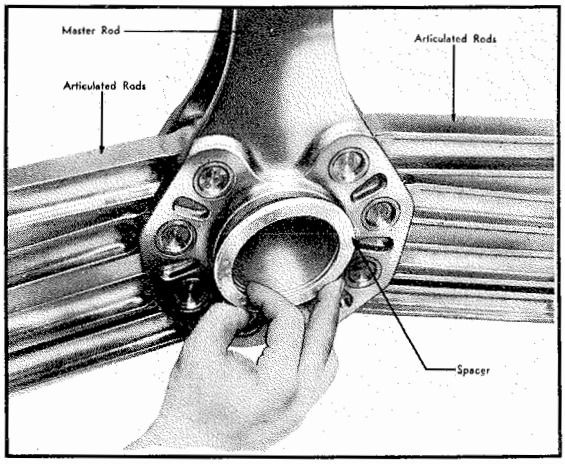



**Fig. 211. Installing Master Rod Spacer**

over the rear end of the master rod hub. Push the master and articulated rod and end seal assembly forward on the crankpin until the end seal disk is contacting the shoulder at the front end of the crankpin.

Install the crankshaft rear end on the crankpin, using the spreader plug (Tool No. 84765-1), plate (Tool No. 84765-2), and screw (Tool No. 84699) in the same manner as previously described for the use of these tools. See figure 212. Insert a feeler gage of the

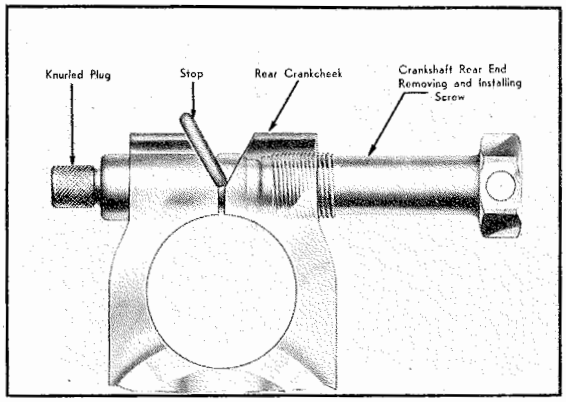
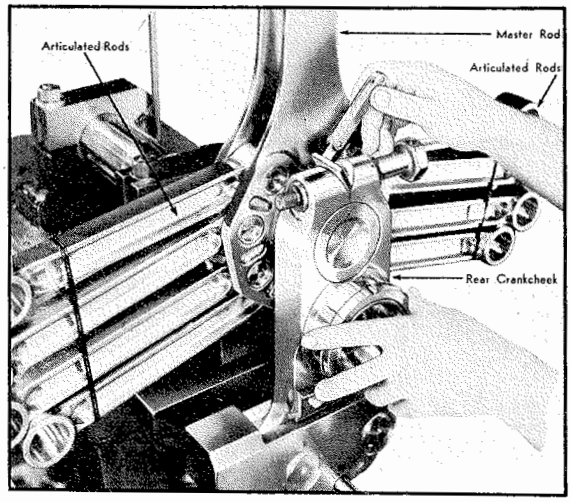



**Fig. 212. Installing Rear Crankcheek**

proper thickness between the master rod end seal spacer and the crankshaft rear. See Fig. 213. Push the crankshaft rear forward on the




**Rod Fig. 213. Measuring Clearance Between Master Rod and Rear Crankshaft**

crankpin until the feeler gage is held firmly between the two parts, thus insuring that the proper master rod end movement is obtained. (Refer to the applicable Table of Limits.) Turn the crankshaft rear on the crankpin until the smallest of the selective fit aligning bars (Tool

No. 80443) may be inserted through the holes in the crankshaft front and rear counterweights, and remove the installing tools. Lubricate the threaded portion of the clamping cap screw hole in the crankshaft rear with Lubriplate 130-A, or its equivalent, and install the chamfered washer and clamping cap screw finger tight. CAUTION: Insure that none of the lubricant is deposited on the crankpin clamping surface, since this will seriously impair the clamping action of the crankshaft rear. If this condition is encountered, disassemble the parts, clean thoroughly, and reassemble as previously outlined.

Align the crankshaft rear end to the crankshaft front end in the following manner: Insert the medium and largest selective fit aligning bars (Tool No. 83576 and 83577, respectively) through the holes in the crankshaft front and rear counterweights. Tap the side of the crankshaft rear using a fiber or hard rubber mallet until this part is aligned with the crankshaft front end, when the largest selective fit aligning bar (Tool No. 83577) is used. See figure 214. The position of best

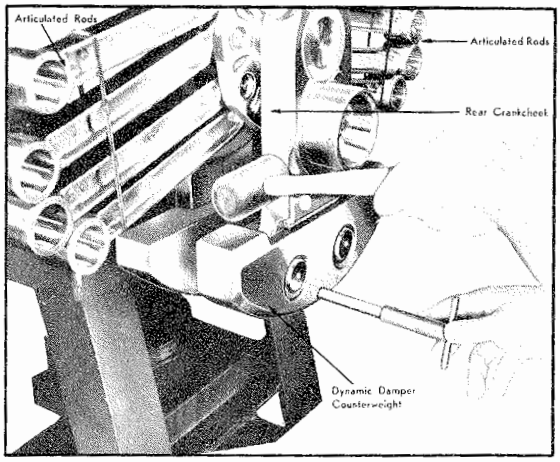



**Fig. 214. Aligning Crankshaft Rear**

alignment may be determined by the ease with which the aligning bar may be inserted in the holes. Binding of the bar upon insertion indicates misalignment of the parts. CAUTION: Do not tap the crankshaft rear when the aligning bar is inserted in the crankshaft front end, as this may bend the bar.

Before tightening the clamping cap screw, with the cap screw finger tight in the crankshaft rear, install the cap screw stretch measuring tool (Tool No. 82200) on the ends of the cap screw. The balls on the tool contact the chamfered sides of the counterbores in the ends of the screw. Using a micrometer installed over the balls, measure the distance between the outer ends of the balls. See figure 215. This dimension must be known in order

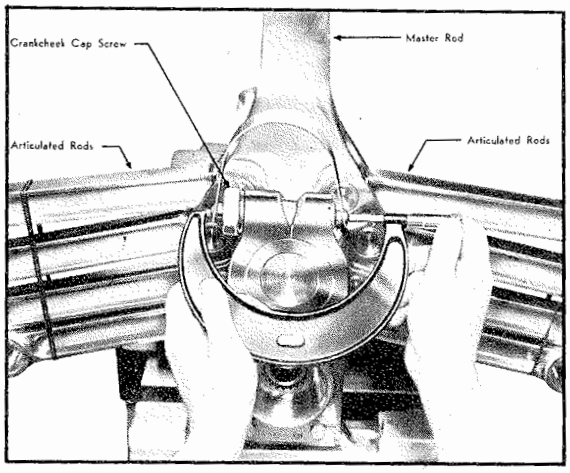



**Fig. 215. Measuring Rear Crankshaft Cap Screw Stretch**

to determine the cap screw stretch after tightening.

Tighten the knurled head bolt underneath the crankshaft rear counterweight to support the crankshaft during the following operations. Tighten the lock nut on the bolt to lock the bolt in the proper position. Tighten the crankshaft rear clamping cap screw using wrench (Tool No. 80309) and extension (Tool No. 80198), until the proper cap screw stretch is obtained, at the same time aligning the the cotter pin hole in the threaded end of the cap screw with its mating hole in the crankshaft rear. See figure 216. Reinstall the stretch measuring tool over the cap screw and measure the distance between the outer ends of the balls as before. The cap screw stretch is the difference between the two micrometer readings. Insure that the stretch is within the proper limits. (Refer to the applicable Table of Limits.)

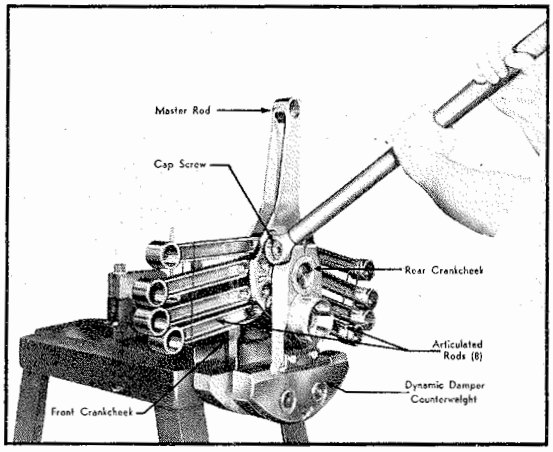



**Fig. 216. Tightening Rear Crankshaft Cap Screw**

Lock the cap screw by inserting the cotter pin in the cap screw from the inside of the cap screw at the threaded end, allowing it to protrude through the crankshaft rear approximately ⅜ inch (9.53 mm). See figure 217.

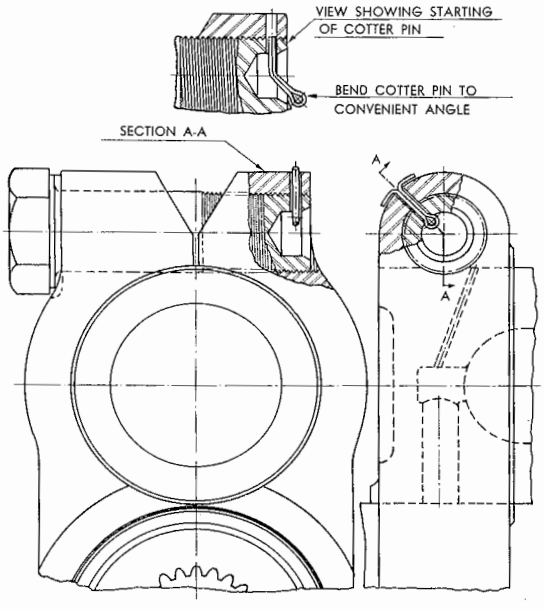



**Fig. 217. Cotterpinning Rear Crankshaft Cap Screw**

Bend down the legs of the cotter pin. If the hole in the cap screw is not aligned with its mating hole in the crankshaft rear when the cap screw is tightened to the proper stretch, it is permissible to drill a new cotter pin hole in the end of the cap screw. Insure that the new hole is located a minimum distance of ¼ inch (6.35 mm), measured at the root of the cap screw thread, from any adjacent hole. It is also permissible to grind either face of the chamfered cap screw washer in order to locate an undrilled portion of the cap screw under the cotter pin hole in the crankshaft rear. If this is done, break all sharp edges to a 1/64 inch (0.397 mm) radius after grinding.

At this time, recheck the master rod end movement by inserting a feeler gage between the master rod end seal spacer and the crankshaft rear, when the master and articulated rod assembly is in the extreme forward position.

Install the crankshaft rear main bearing as follows: Heat the rear main bearing inner race for 10 minutes in an oil bath maintained at a temperature of 225 deg. F. (107 deg. C.), and install over the crankshaft rear extension. Insure that the lip on the outside diameter of the inner race is facing toward the crankshaft rear cheek. Tap the rear end of the inner race after installation to insure that it is bottomed on the shoulder on the crankshaft rear end.

Install the crankshaft rear main bearing outer race, retainer, and rollers on the inner race. Insure that the side of the outer race marked "PROPELLER END" is facing toward the crankshaft rear cheek. Install the crankshaft rear main bearing nut, and tighten, lining up one of the tapped holes in the nut with one of the drilled holes in the crankshaft rear extension. See figure 218. Install a

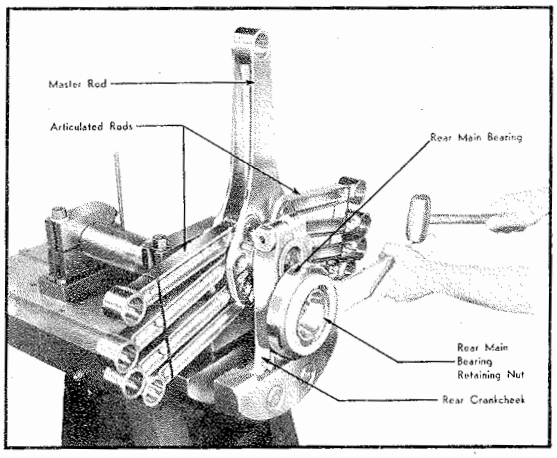



**Fig. 218. Tightening Rear Main Bearing Retaining Nut**

new tab lock and the rear main bearing nut locking cap screw or tighten the lock screw and bend up the tab lock to secure it.

Remove the crankshaft assembly from the assembly and disassembly fixture and install on two alignment checking rollers (Tool No. 82658), in order to check the crankshaft alignment. Turn the crankshaft on the rollers and using a dial indicator mounted on a surface gage, check the run-out at the front and rear propeller shaft bushing journals on the crankshaft. (Refer to the applicable Table of Limits for the allowable run-out at these locations.) If the crankshaft run-out is not within the specified limits, the crankshaft alignment is not sufficiently accurate. If this condition is encountered, it will be necessary to reassemble the crankshaft to obtain proper alignment as determined by the run-out check on the rollers.

At this time, check also the clearance between the shank of the master rod and the front surface of the rear counterweight or counterweight pins, whichever is closer to the rod. When making this check, hold the master rod in the extreme rear position on the crankpin, with the end seal spacer contacting the crankshaft rear. The minimum permissible clearance in this location is .038 inch (0.965 mm).

# CYLINDERS AND PISTONS

Refer to the sections entitled REPAIR PROCEDURE, STUD REPLACEMENT, and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**PROFILING CYLINDER HEAD FINS** Rework cracked or broken cylinder head fins by profiling to the depth of the crack provided the crack does not extend into the dome of the cylinder head, and provided the total amount of fin metal removed in this manner does not exceed 14 square inches, (84 sq. cm.) per cylinder. Fin metal may be removed from a single fin or from several fins provided the total metal removed does not exceed the limits specified. Fins on any part of the cylinder head may be reworked.

In profiling a fin, use a thin burring tool or grinding wheel operated on a flexible shaft. Exercise care to prevent cutting into the dome of the cylinder head, to prevent scratching adjacent fins, and to remove all sharp corners on reworked fins. Other cracks may be started from scratches or sharp corners if these are not removed. For this reason, reworked areas must be smoothly profiled and blended with a minimum radius of .250 inch (6.35 mm).

If it is necessary to profile a fin to the outside surface of the dome of the cylinder head, perform the following inspection to insure that the crack in the fin has not extended into the dome of the cylinder: Etch locally the outside surface of the dome adjacent to the reworked fin by swabbing with a 10-20% caustic soda solution for 7 to 10 minutes. Swabbing or rubbing is necessary to accomplish continuous removal of the aluminum oxides as they are formed and to work the caustic soda into any crack that may be present. Then swab the same area with a 35-65% solution of nitric acid to brighten the surface and reveal any crack that may be present as a black line. If no cracks are found, wash the head thoroughly with water to remove the etching solutions. The presence of a crack in the surface of the dome is cause for rejection of the cylinder.

After profiling and etching, paint the profiled area with lacquer or enamel.

**HONING AND GRINDING CYLINDER BARRELS** The condition of a cylinder barrel and the amount of taper, out-of-round, and wear will determine the operations to be used in reconditioning a cylinder barrel bore. If the following maximum diameter or taper limits for straight and choke bore cylinders are exceeded, the barrel should be ground to .015 in. (.381 mm) oversize, or scrapped if the oversize limits have been exceeded. When measuring choke cylinders for taper, reference should not be made to the reduced diameter in the choke area.

| Limit | Standard Bore | .015 in. (.381 mm) Oversize Bore |
|---|---|---|
| Maximum diameter | 6.135 in. (155.829 mm) | 6.150 in. (156.210 mm) |
| Taper | .010 in. ( .254 mm) | .010 in. ( .254 mm) |
| Out-of-round | .005 in. ( .127 mm) | .005 in. ( .127 mm) |

**LAPPING** To remove surface glaze for better ring seating, cylinder barrels which are within service dimensional limits should be lapped only, in order to hold the amount of material removed from any cylinder at a minimum. Ring steps at the top of the barrel should be blended prior to lapping. Cylinders which have been re-ground must be lapped.

(1) Wash thoroughly with Varsol to remove all grease and oil.

(2) Remove ring markings in the lower skirt area by lapping this section 10 to 15 complete strokes before lapping the full length of the barrel.

(3) Using a minimum of 100 strokes (50 in and 50 out), lap the barrel until a uniform "satin" finish is obtained. A suitable lap may be made with a .015 in. (.381 mm) oversize dummy piston incorporating a wooden stop fastened to the piston dome on the combustion chamber side to prevent the top ring on the piston from catching at the top of the sleeve. Use standard size rings with a 45 deg. x 1/32 in. chamfer on the outer edges, installing them in the grooves above the piston pin only. The piston and rings should be replaced when the clearance and wear become excessive. Apply a moderate amount of not-too-dry medium lapping compound to the piston and cylinder skirt.

(4) Use a straight reciprocating motion, rotating the piston approximately 60 deg. with each stroke, to spread the compound evenly about the barrel bore. Lapping may be done by hand or by a power-driven machine incorporating a twisting action. If a Barnes honing machine is available, a lapping piston may be attached by use of adapter No. 803568. All compound must be cleaned from the machine after lapping, and care must be taken to prevent any compound from entering the coolant system.

(5) Clean the barrel thoroughly, scrubbing the bore with Varsol or with a hot soap and water solution. Clean the intake port and the intersection of the cylinder head and barrel with particular care to insure that no compound is present. Do not use an air blast for cleaning as it may pack the abrasive solidly into corners and recesses.

(6) Lapped barrels are particularly susceptible to corrosion and hence should be slushed immediately after cleaning. If cylinder barrels are to be stored even for a short period after reconditioning, they should be oiled with compound, W.A.C. Specification 5842.

**BLENDING RING STEPS** To prevent ring breakage ring steps, usually found at the head end of the cylinder barrel, should be smoothed out prior to lapping or honing if the step is sharp or exceeds .005 in. (.127 mm) in depth.

(1) For moderate localized grinding an abrasive-charged felt wheel turned by a 14,000 rpm "Thor" bantam rotary air grinder Model 0000 may be used. Wheels may be fabricated by rolling 3 in. (76.2 mm) x ½ in. (12.7 mm) hard piano felt disks in Le Page's glue and then in Alundum (aluminum oxide), grain size No. 180, or a comparable abrasive grit. Dry the disks in an oven and store in a dry place. Worn wheels may be dressed down in a lathe and recoated with abrasive for further use.

(2) For localized grinding to remove deep ring steps, time may be saved by using a grinding jig (Tool No. 803264) which incorporates an eccentric spindle that controls the depth of the cut of the wheel. Material is removed at the step only. Use grinding wheels 4½ in. (114.3 mm) x 1¼ in. (31.75 mm) x 2 in. (50.8 mm) of the type recommended under GRINDING which have been dressed down to give a negative or "antichoke" taper

of .010 in. (.254 mm) in the 1¼ in. (31.75 mm) wheel thickness. Set the wheel to remove all material on the side of the bore where the ring step is least pronounced, being careful to avoid touching that section of the barrel with which the rings come in contact. Remove any grinding marks and the portion of the ring step that still remains on the deep side by hand stoning or with a rotary air grinder. Further conditioning of the ring step area will not be necessary prior to lapping if chatter marks and grinding ridges are avoided.

(3) As an optional method, 4¼ in. (107.95 mm) Micromatic Hone Corp. No. 3201 sticks may be used. Two-thirds of the stick is composed of cork in order to permit the stone to follow the contour of the bore in the choke area. Refer to HONING for the proper head to be used. Adjust the stroke to confine the stones to the step area to avoid unnecessary removal of stock in the straight portion of the bore. It may be necessary to finish the blending by hand or with a rotary air grinder to avoid excessive removal of material in the choke area.

(4) Hand stoning may be used for slight ring steps, but it is a very slow and tedious operation.

**HONING** Cylinders which evidence excessive corrosion pitting, large sharply defined hollow spots, or score marks that cannot be removed by lapping should be honed. If it is necessary to remove more than .005 in. (0.127 mm) of material to correct for excessive taper, out-of-round, or scoring in a cylinder barrel, grinding should be done since a hone tends to follow the contour of a worn cylinder bore. Honing should be used in moderation to produce a surface finish suitable for lapping. All barrels must be lapped after honing.

(1) In honing straight bore cylinders, use Carborundum hone stone B500MHE6 running at approximately 39 rpm and 26 to 27 strokes per minute. Michromatic honing head (Tool No. 802096) or for large quantities of barrels (Tool No. 800040) may be used. See figure 219.

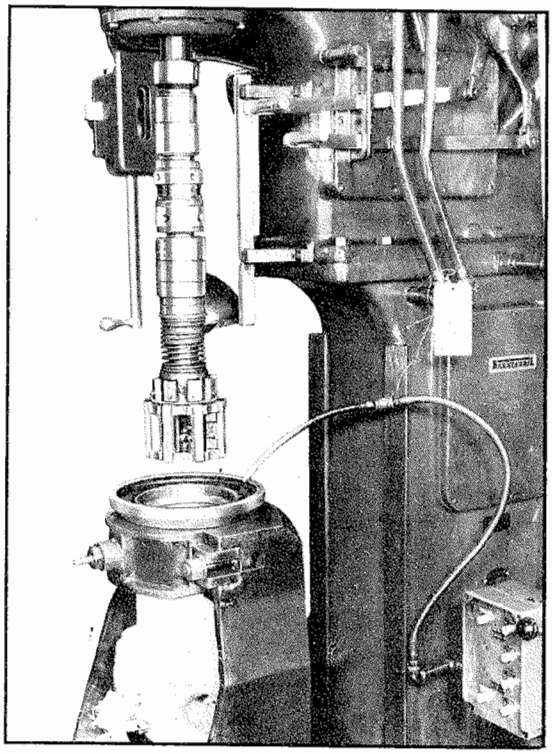


**Fig. 219. Honing Cylinder Bore**

In honing choke bore cylinders, the same stone (B500MHR6) may be used but must incorporate a ⅛ in. (3.175 mm) radius at the lower end of the stone to prevent digging into the barrel choke. Micromatic honing head (Tool No. 802096) is required for choke barrels. The .010 in. (0.254 mm) wear limit may be exceeded in the choke portion of a choke bore barrel up to the maximum diametral dimension permitted in the straight portion; however, as much choke as possible should be maintained in the upper 2 in. (50.8 mm) of the barrel.

(2) A suitable honing lubricant may be made as follows: 5 parts of kerosene oil to 1 part of Internation 155-D-S compound by volume.

(3) Scored cylinder barrels that are honed must be magnetically inspected. If minute cracks are still in evidence, they must be entirely removed by grinding as they may form a source of fatigue failure.

**GRINDING** Cylinder barrel bores should be ground if it is necessary to remove more than .005 in. (.127 mm) of stock

from the diameter. If the wear limit has been exceeded and oversize piston assemblies are available, cylinder barrels may be ground to .015 in. (.381 mm) oversize. It is recommended that oversize cylinder assemblies be installed on the engine in complete sets as a precaution against accidental interchanging of cylinders and pistons.

(1) The following grinding wheels are recommended:

Carborundum G90PW 4½ in. (114.3 mm) x 2 in. x 2 in. (50.8 mm)
Norton 3760H
Macklin AY2-307-1850B, Process 402

(2) A suitable grinding lubricant may be made by mixing 1 part of Internation compound No. 137 with 75 parts of water.

(3) Center the cylinder on an internal grinding machine by indicating the inside diameter of the barrel bore at the cylinder flange location to insure that the cylinder bore will be ground true with the mounting flange. Adjust the work spindle drive to a speer of 120 rpm and the grinding spindle to a 4½ in. (114.3 mm) wheel speed of 6,000 ft. per min. (4,800 to 5,000 rpm). Set the grinding spindle feed at 4 ft. per min. and adjust the stops so that the wheel will travel beyond both ends of the cylinder barrel. To prevent the wheel from cutting the cylinder head, do not permit the leading edge of the wheel to travel more than ⅛ in. past the upper end of the barrel.

(4) Cam actuated choke bore grinding machines, if available, should be used for regrinding choke bore cylinder. When grinding either straight or choke cylinders to .015 in. (.381 mm) oversize, a choke may be ground in the head end of the barrel if the maximum bore dimension at the top of the ring travel does not exceed 6.135 in. (155.829 mm). If the bore is larger at this point, the barrel should be ground straight. If the choke does not extend to the head end of the barrel after grinding, blend this area by honing as described under BLENDING RING STEPS—Item (3). Dimensions for grinding oversize choke bore cylinders are shown in figure 220.

(5) If the grinding operation does not result in a uniformly smooth surface finish, it will be necessary to hone the barrel prior to lapping. If the barrel finish is from 10 to 20 micro inches and there are no grinding or chatter marks, it will not be necessary to hone before lapping. All barrel bores must be lapped prior to their being placed in service.

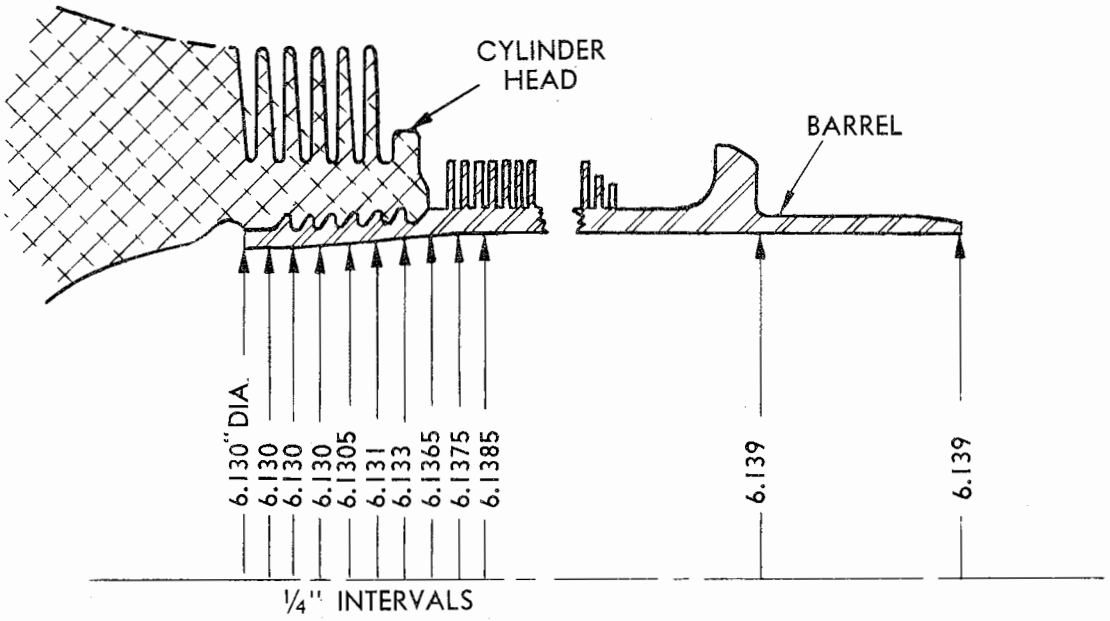



**Fig. 220. Choke Bore Dimensions**

**INTAKE PIPE FLANGE CAP SCREW BUSHINGS** Two types of intake pipe flange cap screw bushings are used in the Cyclone 9GC engine, one blind bushing and two open bushings.

To remove these bushings force the removing tool (Tool No. 801163) in with a hammer to a depth of about ⅜ inch (9.54 mm), and unscrew the bushing with a wrench on the tool square.

Bushings and taps are supplied in the following oversizes: .003, .007, and .012 inches (0.076 mm, 0.178 mm, and 0.305 mm). The taps are numbered respectively (Tool No. 84840, 83639, and 84610).

For blind screw bushings retap the hole in the cylinder head to a depth of .46 to .59 inch (11.7 to 15.0 mm) while for open bushings retapping should be carried to a depth of .55 to .75 inch (14.0 to 19.0 mm).

Before heating the head try the new bushing in the hole. Select a bushing that will enter the head for about three threads when cold. Heat the cylinder in an oven to 300 deg. F. (149 deg. C.) for twenty minutes. Screw in the bushing with a 9/16 inch wrench until it bottoms. Using counterbore (Tool No. 800976), holder (Tool No. 82297), and pilot (Tool No. 83641) face the bushing from 0.00 to .02 inch (0.00 to 0.51 mm) below the surface of the mounting flange.

Retap inside of bushing with tap (Tool No. 83642) to a depth of .52 to .75 inch (13.2 to 19.0 mm) and countersink to a diameter of .32 inch (8.1 mm) using a standard 90 deg. countersink.

Blind bushings should be replaced with oversize blind bushings and open bushings with oversize open bushings.

**AIR DEFLECTOR CAP SCREW BUSHINGS** To replace an air deflector cap screw bushing drill out the old bushing using a size 25/64 inch drill (Tool No. 84278). Remove the remaining thin shell of the bushing and retap the hole to clean up the threads in the cylinder head using a 7/16-20 tap, (Tool No. 800214).

Before heating the head try the new bushing in the hole. Select a bushing that will enter the head for about three threads when cold. Heat the cylinder in an oven to 300 deg. F. (149 deg. C.) for about 20 minutes. Coat the bushing with Lubriplate, or its equivalent, place it on a driver and install the bushing. Suitable drivers can be made from a piece of hexagonal stock with one end turned down and threaded, ¼-28, enough to accommodate both the bushing and a lock nut. Screw in the bushing until it bottoms in the hole. Remove the driver and allow the cylinder to cool. Spotface newly installed bushings to a depth of approximately .015 inch (0.381 mm) below the head surface. Run a ¼-28 tap, (Tool No. 800643) into the bushing to clean up the threads.

**ROCKER BOLT BUSHINGS** Engines equipped with rocker arm bolt bushings in the rocker box bosses, should be inspected and replacement made where necessary in the following manner: Place the puller collar (Tool No. 800099-3) between the rocker box bushings with the large end over the shoulder of the bushing to be removed. Insert the puller arbor (Tool No. 800099-1) through both bushing holes entering it from the side from which the bushing is to be removed. Place the puller bushing (Tool No. 800099-5) on the arbor, push it through the opposite bushing and locate it against the collar. Attach the puller nut (Tool No. 800099-7) to the arbor. Hold the knurled handle of the arbor and with handle (Tool No. 81403) or suitable ⅞ inch (22.2 mm) wrench, screw the nut on the arbor and remove the bushing. Remove the nut and bushing from the arbor. Remove the arbor, collar, and old bushing from the rocker box.

Remove the bushing from the opposite side in the manner just described, except reverse the position of the tools in the rocker box and in addition insert sleeve (Tool No. 800-099-8) in the hole from which the first bushing was removed. Remove the bushing. Remove the puller tools.

Remove burrs or nicks from the rocker box bushing holes and finished surfaces.

Check the outside diameter of the new

bushing and the inside diameter of the rocker box holes to obtain the correct shrink fit. (Refer to the applicable Table of Limits.)

To install the first of the two rocker box bushings, heat the cylinder in an oven to 250 deg. F. (121 deg. C.). If a heating oven is not available, the rocker bosses may be heated locally.

Insert the installing collar (Tool No. 800-099-9) in the new bushing and place in position between the rocker box bosses. Install the locating washer (Tool No. 800099-10) in position on the arbor (Tool No. 800099-1) so that the spherical face of the washer will contact the spherical seat on the rocker box when the arbor is in position in the bushing holes.

Insert the arbor with washer through both rocker box bushing holes, starting from the side in which the bushing is to be installed. Place the new bushing and collar on the arbor as it is pushed through. Place the sleeve (Tool No. 800099-8) and bushing (Tool No. 800-099-5) over the end of the arbor and locate them in place. Attach the puller nut (Tool No. 800099-7) on the arbor threads, tightening it until the bushing is in place. Remove the installing tools.

Install the bushing in the opposite side in the same manner and with the same tools described above, except that the tools are installed from the opposite side of the rocker box and the sleeve (Tool No. 800099-8) is omitted.

Line-ream the bushings by hand using reamer (Tool No. 800108) and check the finished hole with plug gage (Tool No. 800111). To avoid scoring the holes do not back the reamer out of the holes.

The fit between the rocker arm bearing and rocker box bushings is obtained by spotfacing the bushing shoulders. Correct alignment at this point is important, therefore the following instructions should be carefully observed.

Place the spotface cutter (Tool No. 800106-2) between the bushing shoulders. Install the washer (Tool No. 800099-10) on the turning bar (Tool No. 800106-11). Insert the bar with washer through the bushing to be faced and slide the cutter in place on the bar. Before securing the cutter to the turning bar, be sure that the washer is installed with the spherical face contacting the spherical seat on the rocker box. Lock the cutter to the bar by means of the setscrew in the cutter. Place the locating plate (Tool No. 800100-1) against the shoulder of the bushing to be faced and the copper shim (Tool No. 800100-2) between the locating plate and the cutter. The copper shim is used to protect the cutting edges of the cutter. Press the cutter against the shim with only sufficient pressure to hold the locating plate in place. Insert the locating plug (Tool No. 800104—exhaust) or (Tool No. 800-102—intake) in the proper valve guide hole and determine the amount of material to be removed from the bushing shoulder by inserting a feeler gage between the "GO" diameter of the locating plug and the end of the locating plate. The bushing should be spotfaced until a .010 inch (0.254 mm) feeler gage enters freely at this point. Recheck this clearance using the "NO GO" diameter of the locating plug. The .010 inch (0.254 mm) feeler gage must not enter when this check is made.

Spotface the opposite bushing in the same manner and with the tools previously described, except that the tools are installed in the reverse position in the rocker box. The locating plate and feeler gage are not used when spotfacing the opposite bushing. Spotface the bushing shoulder to obtain the proper distance between the bushing shoulders. Check this distance with the "GO" and "NO GO" gage.

It is not necessary to remove the cutting tool from the turning bar when checking the progress of the facing operation. To make this check, center the tool between the bushings and slide the "GO" and "NO GO" gage over the cutting tool.

After the bushings have been properly refaced, remove the refacing tools.

**SPARK PLUG INSERTS** To replace a spark plug insert mount the cylinder in the drill press fixture (Tool No. 82955) and adjust the fixture cradle so that the insert is square with the drill press. Use counterbore (Tool No. 82776) with holder (Tool No. 81362) and pilot and nut (Tool No. 81363) to remove 45 deg. shoulder from the outer face of the insert. Use counterbore cutter (Tool

No. 81359) with the same holder and pilot and bore out the insert. Break out the shell that remains and remove the pieces of the old locking pins.

If the insert has been removed without damaging the threads in the head, tap the hole using standard tap (Tool No. 81356) to remove any small nicks and clean the threads. Select a standard insert that will allow the correct drive fit and screw it on the installation tool (Tool No. 81328). Coat the threads of the insert with Heldite or its equivalent, and screw it into the cylinder head until the shoulder on the insert is bottomed against the surface of the cylinder. Remove the tool. This operation is performed with the head and insert both at normal room temperature.

Locate the lock pin drill jig (Tool No. 81323) so that the new holes will be drilled midway between the old lock pin locations. Drill the lock pin holes $^{15}/_{32}$ inch $+$ $^{1}/_{32}$ inch $-$ 0 inch (11.9 mm $+$ 0.79 $-$ 0 mm) deep with a No. 31 (.120 inch) (3.04 mm) drill. Remove the drill jig and drive in the pins. The pins must bottom in the holes and be flush with or extend above the surface of the insert shoulder.

Spotface the insert using the spotface cutter (Tool No. 81360) with holder (Tool No. 83047) and pilot (Tool No. 83049) to a depth sufficient to clean up the face. Remove approximately .010 inch (0.25 mm).

Back spotface the inner face of the insert a sufficient amount to blend the end of the insert into the radius of the cylinder dome and chamfer the thread end using cutter (Tool No. 82793), with pilot (Tool No. 82794) and collar (Tool No. 82796).

Place the spark plug hole tap (Tool No. 81355) in a tap wrench and install the tapping bushing (Tool No. 81358) over the tap. Run the tap through the insert. Remove tap and clean the threads. Oversize spark plug inserts are installed in the same manner as previously described except that the threads in the cylinder head are tapped for .015 inch (0.38 mm) oversize with tap (Tool No. 81357) and for .030 inch (0.76 mm) with tap (Tool No. 82567.)

**REFACING EXHAUST VALVE SEATS** Steel exhaust valve seats should be ground whenever they are pitted, whenever they are not concentric with the valve guides, and whenever a new exhaust valve seat insert is installed in a cylinder head. An exhaust valve seat which is pitted to such an extent that it cannot be fitted for further use by grinding must be replaced with a new part. When an exhaust valve seat is not concentric with its valve guide within the limits specified below, that valve guide must be replaced. If an exhaust valve guide must be replaced because of a bell-mouthed condition, replace that valve guide before making the concentricity check. The concentricity gage will not give an accurate indication if the valve guide is bell-mouthed.

After cleaning the cylinder, carefully examine the condition of the exhaust valve seat. If there are any pits in the seat, the seat must be ground or replaced, depending on the extent of pitting.

Use the bluing gage (Tool No. 800250) to check concentricity. Insert a feeler gage between the valve seat and the bluing gage to determine whether a new valve guide should be installed. If the seat is more than .0075 inch (0.191 mm) out of line with the valve guide bore, measured in this manner, it is recommended that a new valve guide be installed.

If the condition of the exhaust valve seat is such that it requires grinding, as indicated by any of the above checks, or if a new exhaust valve seat insert has been installed in a cylinder, grind the seat in accordance with the following instructions:

Grinding wheel (Tool No. 800606) is used in grinding either 30 deg. or 45 deg. exhaust valve seats. Mount the wheel on the pilot (Tool No. 83767) fixing it tightly with the nut and washer. Set up the wheel and pilot between centers in a lathe and dress the outside diameter of the wheel true to a diameter of $3^{5}/_{32}$ inches (80.16 mm) using a diamond dresser (Tool No. 83362). Dress the parallel, flat surfaces of the wheel square with the

pilot to balance the wheel on the pilot. Remove the wheel and pilot from the lathe, but do not disassemble these parts. If the wheel is disassembled from the pilot, it will no longer be true when reassembled.

Set up the bluing and limit gage (Tool No. 800250) between centers in a lathe. Using an indicator in the tool post, adjust the compound rest to the same angle as the blue gage. Remove the indicator and the blue gage from the lathe. Set up the wheel and pilot between the lathe centers, and insert the diamond dresser (Tool No. 83362) in the tool post exactly the same height at which the indicator was set when the indicator was used to adjust the compound rest. Dress the wheel to the required angle, holding the inner diameter of the angle surface on the wheel to a maximum of $2\frac{21}{32}$ inches (67.4 mm).

To grind the valve seat, mount the cylinder on the holding fixture (Tool No. 82955). Insert the pilot sleeve bushing in the valve guide from the rocker box side. Three pilot sleeve bushings of different sizes are available for oversize valve guide bores so that a selective fit may be obtained. Bushing numbers and sizes are as follows: (Tool No. 83768—0.686 inch outside diameter) (Tool No. 83769—0.688 inch outside diameter) and (Tool No. 83770—0.690 inch outside diameter). Insert the wheel and pilot in the bushing, and lock the pilot to the shaft of a suitable driving machine. Use vaseline to lubricate the pilot in the bushing. Dip the grinding wheel in cleaning gasoline or kerosene before grinding, and wet the wheel frequently while grinding. Adjust the speed of the driving machine to give a wheel speed of approximately 4200 rpm. Lift the wheel from the seat frequently while grinding. After grinding the seat for a short time, check the angle of the seat using the bluing and limit gage (Tool No. 800250). Insert the gage, lightly coated on the face with prussian blue, and give it a few turns to transfer the blue to the seat. If the blue marking on the seat is continuous across the entire width of the seat at all points, the seat angle is correct. If difficulty is encountered in obtaining the proper marking on the seat with the gage, it may be necessary to reset the diamond dresser and redress the wheel before grinding further.

Grind until the correct outer seat diameter is obtained as indicated by the bluing and limit gage (Tool No. 800250). See figure 221

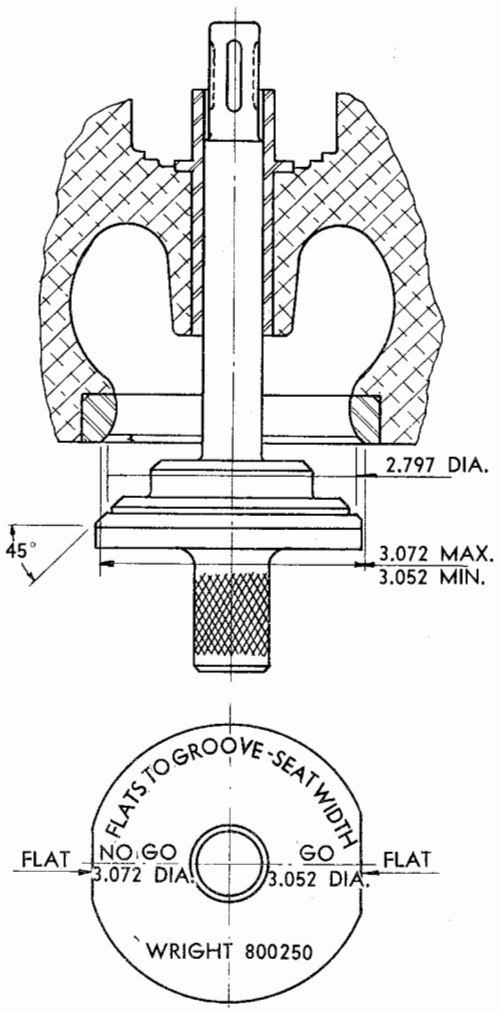



**Fig. 221. Exhaust Valve Bluing and Limit Gage**

for sketch showing the proper use of bluing and limit gage. Coat the face of the gage lightly with prussian blue, place it on the valve seat and give it a few turns to transfer the blue to the seat. Examine the outer diameter of the seat at both the "GO" and "NO GO" flats on the gage. At the "GO" flat the outer seat diameter should be just visible, and at the "NO GO" flat the seat should not be

visible. If the seat is not visible at the "GO" flat, continue grinding until the outer diameter of the seat is just visible at the "GO" flat. If the seat is visible at the "NO GO" flat, grind the outer surface of the insert using grinding wheel (Tool No. 800606). Such grinding is called "narrowing grinding" since the width of the seat is thereby narrowed by reducing the outer diameter of the seat. Grinding wheel (Tool No. 800606) is used in narrowing grinding. Use for this purpose a wheel which has not been dressed to perform any other kind of grinding. Assemble the narrowing wheel to the pilot (Tool No. 83767) and mount between centers in a lathe. Dress the outside diameter of the wheel true to a diameter 1/32 inch (0.78 mm) less than the diameter of the exhaust valve seat insert bore in the cylinder head, and dress the parallel, flat surfaces of the wheel square with the pilot. Extreme caution must be used in obtaining the diameter of the outside diameter of the wheel. The outside diameter of the wheel must be small enough so that the wheel will not touch the cylinder head around the insert when grinding, and large enough so that the outer surface of the insert will be ground 1/64 inch (0.38 mm) from the sides of the cylinder head bore. After dressing the wheel, install the pilot sleeve bushing in the valve guide as before, and remove the wheel and pilot from the lathe and install in the bushing. Grind the outer surface of the exhaust valve seat insert until the outer diameter of the seat is just visible at the "GO" flat on the bluing and limit gage.

The correct inner diameter of the seat is the diameter of the outer edge of the groove cut in the face of the bluing and limit gage (Tool No. 800250). Coat the face of the gage lightly with prussian blue, place the gage on the seat and give it a few turns to transfer the blue to the seat. Remove the gage and examine the blued surface of the seat and the gage. If the correct inner seat diameter has been obtained, the blue marking on the seat will extend across the entire width of the seat, and the blue will be removed from the gage to the outer edge of the groove cut in the gage face. If the inner diameter of the seat is too large, the blue on the seat will extend across the entire width of the seat, but it will be observed upon examination of the gage that a circular strip of blue has been left on the gage face next to the outer edge of the groove. If such an indication is obtained, continue grinding until the width of the seat extends to the outer edge of the groove in the gage. If the inner diameter of the seat is too small, there will be a circular strip on the surface of the seat which has not been touched by the blue. If such an indication is obtained, carefully dress a grinding wheel to conform to the inside surface of the exhaust valve seat insert. Grind the inside surface to blend into the inner diameter of the circle of blue on the seat, which is the correct inner seat diameter.

Recheck the angle of the exhaust valve seat after grinding using the bluing and limit gage as described above. If the correct seat angle has not been obtained, continue grinding, redressing the grinding wheel if necessary. Recheck the concentricity of the seat per instructions at the beginning of this section. If the seat is more than .003 inch (0.076 mm) out of line with the valve guide bore, continue grinding.

The foregoing describes the valve seat grinding procedure when using portable type equipment where the volume of work is not particularly large. For overhaul shops where the volume of this work is very large there is available other machine equipment which will perform the work more rapidly. Information concerning this equipment can be obtained through the Service Division of the Wright Aeronautical Corporation.

**REPLACING EXHAUST VALVE SEATS** Replace exhaust valve seats that are badly burned or pitted to such an extent that they cannot be reconditioned for further use by grinding.

To remove a steel exhaust valve seat insert it is necessary to bore a 1/64 inch (0.39 mm) shoulder in the exhaust port behind the insert upon which the drift may rest.

To bore the port behind the insert, mount the cylinder on the holding fixture (Tool No. 82955) and use the boring tool (Tool No. 800209). Set the tool bit with the gage (Tool No. 801287). Insert the boring tool in the

valve guide from the inside of the cylinder, and insert the bushing (Tool No. 800206) and stop collar (Tool No. 800209-2) on the boring bar. Bore the port behind the insert, thus leaving a shoulder of the insert exposed upon which the drift may rest when driving out the insert. Remove the tools from the cylinder and remove the cylinder from the holding fixture. The above operation applies to first seat replacement only.

Heat the cylinder in a flameless type oven to 300 deg. F. (149 deg. C.). Install the cylinder wall protecting sleeve (Tool No. 800208) and mount the cylinder on the holding stand (Tool No. 800207). Use removing drift (Tool No. 801286) which is flattened on two sides so that it may be passed up through the seat and placed into driving position on the exposed portion of the valve seat insert. Install the bushing (Tool No. 800206) in the valve guide and place the plug (Tool No. 800207-14) in the bushing. Place the punch (Tool No. 800207-12) on the plug. Place the guard (Tool No. 800207-13) over the end of the punch and drive out the seat. Remove the tools from the cylinder and the cylinder from the holding stand.

Check the diameter of the seat recess in the cylinder head and the outside diameter of the new steel exhaust valve seat to determine the correct shrink fit. (Refer to the applicable Table of Limits.) Recesses that are damaged when removing the old valve seat insert or that will not allow the correct shrink fit should be bored out to accommodate an oversize insert.

Oversize counterbore cutters for enlarging the diameter of the valve seat insert recess are available in the following tool numbers:

| Oversize of Insert | Use Counterbore Cutter, Tool No. |
|---|---|
| 0.010 inch | 800331 |
| 0.020 inch | 800332 |
| 0.030 inch | 800333 |
| 0.040 inch | 800334 |

Bore the exhaust valve seat insert recess in the cylinder head to the proper oversize diameter, using the counterbore cutter selected and bushing (Tool No. 82536), pilot (Tool No. 82532), jack (Tool No. 82522) and handle (Tool No. 82519). Insert the bushing in the valve guide from the rocker box end of the guide. Mount the cutter on the pilot, and insert the pilot in the bushing. Place the jack over the end of the pilot in the rocker box, resting the base of the jack on the valve guide shoulder. Lock the handle to the end of the pilot with the pilot locking pin. Adjust the depth of cut by raising the jack. The counterbore cutter is also used to increase the depth of the recess, where this is necessary. Care must be taken to obtain a smooth surface at the bottom of the recess.

Check the diameter of the recess after boring and select the proper oversize steel exhaust valve seat insert. Place the insert on the installing tool (Tool No. 800356). Submerge both the tool and the insert in a solution of denatured alcohol and dry ice, and chill thoroughly. Heat the cylinder in an oven for one hour at 600 deg. F. (316 deg. C.). Install the insert in the cylinder head recess and pull it into place with the puller (Tool No. 81171) and handle (Tool No. 81174). Allow the cylinder to cool in the air before removing the installing tool.

Check the concentricity of the seat with the valve guide, using blue gage (Tool No. 800250) by inserting a .0075 inch (0.19 mm) feeler gage between the blue gage and seat. If the gage is loose the valve guide must be replaced. If the valve guide must be replaced, perform that replacement before grinding the seat.

Grind the exhaust valve seat.

**REFACING AND REPLACING INTAKE VALVE SEAT INSERTS** For refacing and replacing intake valve seat inserts, observe the procedure described above for exhaust valve seat inserts. Use the same tools for these operations as are used for exhaust valve seats with the exception of those listed below:

800249 Gage—Intake Valve Seat Bluing and Limit

800168 Pilot—Washer and Nut, Intake Valve Seat Grinding Wheel

800189 Bushings—Intake Valve Seat Grinding Wheel Pilot (Selective Fit No. 1)

800190 Bushings—Intake Valve Seat Grinding Wheel Pilot (Selective Fit No. 2)

800191 Bushings—Intake Valve Seat Grinding Wheel Pilot (Selective Fit No. 3)

800795 Diamond—Grinding Wheel Dressing

801947 Drift—Intake Valve Seat Removing

801948 Gage—Intake Valve Seat Boring Tool Setting

800205 Bushing—Intake Valve Seat Removing Tools, Pilot Drill Press and Bench

800330 Bushing—Intake Valve Seat Oversize Recess Cutter, Pilot

800355 Intake Valve Seat Installing Tool

**VALVE GUIDES** If the valve guides do not require replacement, clean the bores with crocus cloth and gasoline. To replace a guide, mount the cylinder in drill press fixture (Tool No. 82955). Do not attempt to pull the guide as this procedure may damage the cylinder head. Bore out the guide using the counterbore cutter and pilot (Tool No. 800572) for intake (Tool No. 82291) for exhaust and holder (Tool No. 82297). A thin shell will remain in the cylinder head. Break out this shell, being careful not to damage the bore in the cylinder head. Check the diameter of the bore in the cylinder head and the outside diameter of the valve guide to be used and refer to the applicable Table of Limits for the correct shrink fit. If the bore in the cylinder head has not been damaged and is smooth, a standard valve guide may be installed.

Intake valve guides are furnished in the following oversize outside diameters: .005, .010, .020 and .030 inch (0.127, 0.254, 0.508, and 0.762 mm). Corresponding oversize reamers are supplied under the following numbers: (Tool No. 800341, 800342, 800343 and 800344). Use pilot bushing (Tool No. 82820) with the above reamers. Check the diameter of the reamed hole using the gage corresponding to the size of the reamer used. Corresponding gages are furnished under the following numbers: (Tool No. 800346, 800347, 800348 and 800349).

Exhaust valve guides and reamers are furnished in the following oversizes: .005, .010, .020, and .030 inch (0.127 mm, 0.254 mm, 0.508 mm, and 0.762 mm). Corresponding oversize reamers are supplied under the following numbers: (Tool No. 83477, 83478, 83479, and 83480). Use pilot bushing (Tool No. 800337) with the above reamers. Check the diameter of the reamed hole using the gage corresponding to the size of the reamer used. Corresponding gages are furnished under the following numbers: (Tool No. 82755, 80431, 80852, and 81473).

Heat the cylinder in a flameless oven for one hour at 300 deg. F. (149 deg. C.). Place the guide to be installed on the installing arbor (Tool No. 800573) for intake and (Tool No. 82125) for exhaust and chill to 20 deg. F. (—7 deg. C.) for 20 minutes. (Refer to the section of Appendix entitled SHOP MATERIALS). Remove the cylinder from the oven and insert the guide in such a position that the oversize markings stamped above the shoulder (in cases where an oversize guide is being installed) are toward the push rod end of the rocker box. Allow the cylinder to cool long enough for the head to grip the guide, then strike the end of the arbor a sharp blow with a hammer to insure the guide is properly bottomed. Remove the arbor and allow the cylinder to cool in the air. After a valve guide installation it is imperative that a check be made to insure that the valve seat insert is bottoming correctly. Try a .001 inch (0.025 mm) feeler between the cylinder recess and the insert. If the feeler does not enter at any point it is an indication that the insert is bottoming correctly. However, if the feeler does enter at any point, the insert should be removed and replaced in accordance with the above instructions covering replacement of exhaust valve seats. Ream the valve stem hole to size using reamer (Tool No. 800340) and wrench (Tool No. 83169) for intake or reamer (Tool No. 83476) and wrench (Tool No. 83006) for exhaust. Use pilot bushings (Tool No. 800336) for intake and (Tool No. 800337) for exhaust. Check the finished size using gage (Tool No. 800345) for intake or (Tool No. 82641) for exhaust. Clean the bores with crocus cloth. Reface valve seats after installation of new guides.

**VALVES** Stone burrs or nicks from the valve spring washers and from the valve split locks.

If a valve face is pitted or warped, reface it in a valve refacing machine. Remove no more metal than is absolutely necessary to true up the face.

When exhaust valves are refaced a sharp edge sometimes remains on the outside diameter of the face. After regrinding valves, it is recommended that this edge be checked, and if necessary, it should be broken to a .010 inch (0.25 mm) minimum radius with a hand stone while the valve is rotating in the refacing machine.

Valve stems become glazed, discolored and in some cases coated with carbon during engine operation. These surfaces should be polished by the use of a stitched cloth type buffing wheel which will remove the carbon deposits and discoloration but will not disturb the glaze, or by the use of crocus cloth and gasoline with the valve stem locked in a rotating lathe chuck as in figure 222. Exhaust valves have nitrided stems and stellite faces. Do not attempt to remove score marks or pitting which require removal of more than .005 inch (0.127 mm) metal from the stem.

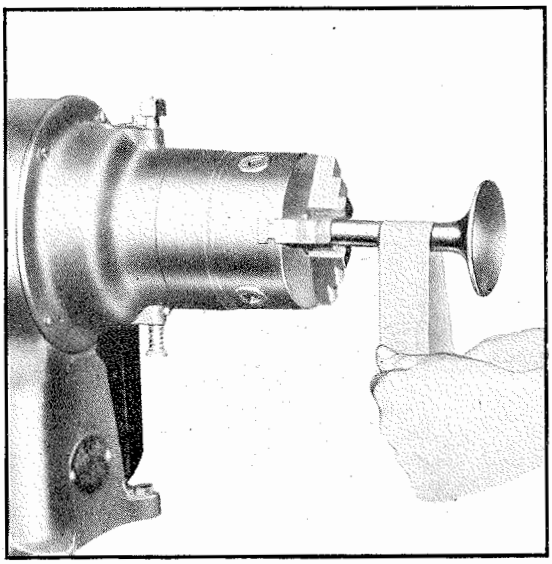


**Fig. 222. Polishing Valve Stems**

Light scores or pit marks may be removed by grinding and polishing.

Standard exhaust valve stems are .6820 to .6825 inch (17.32 to 17.34 mm) in diameter. The maximum limit to which an exhaust valve stem may be reground is .677 inch (17.19 mm) in diameter. If the pits or score marks cannot be removed by regrinding to the above dimensions, replace the valve.

If grinding facilities are not available, valves may be returned to the factory for possible reconditioning by regrinding of the stem or restelliting of the face.

Polish the valve head with crocus cloth and gasoline to remove all scratches.

Stone light scores and remove all burrs from the valve lock recess.

Grind the faces of exhaust valves to an angle of 43 deg. 30 min. + 15 min. — 00 min.

Grind valve faces as follows: Set up the valve refacing machine and accurately grind the valve face to the required angle. Use angle checking blue gage (Tool No. 800500) for exhaust valves with 43 deg. 30 min. + 15 min. — 00 min. angle. Coat the seat angle on the blue gage lightly with prussian blue, insert the valve in the gage, rotate it so that the blue will be transferred from the gage to the valve face, then remove and inspect the valve face for correct angle. The valve face angle may only be considered satisfactory when contact around the entire circumference of the valve face is obtained.

Check the tightness between the valve face and valve seats as follows: Assemble the valves in the cylinder as described below under ASSEMBLY, being sure the faces of the valve and valve seat are free of dust or dirt. Insert dummy or other suitable spark plugs in the spark plug inserts. Place the cylinder on a bench with the skirt of the cylinder up, pour enough unleaded gasoline into the cylinder to cover the heads of the valves and with suitable plugs inserted in the exhaust and intake ports apply an air pressure of 5 to 8 pounds per square inch (0.351 to 0.56 kg./sq. cm.) in each valve port successively. If no air bubbles are noted in the gasoline, the valves and valve seats are satisfactory. If air bubbles are present, disassemble the defective valve from the cylinder and regrind the valve face and valve seat, reassemble the valve in the cylinder and repeat the test. If a valve

does not air-test satisfactorily after regrinding, it is permissible to lightly lap the valve into the seat, provided the differential seat angles are not materially changed and the width of the lapped valve face and valve seat do not exceed 1/16 inch (1.58 mm).

Before attempting to perform a lapping operation, thoroughly inspect the grinding equipment for defects, the grinding wheels for correct angles and the valve seat for concentricity with the valve guide.

To perform the lapping operation apply a small amount of 3 M Oil Mixed Lapping Compound, or its equivalent, to the valve face at the large diameter of the angle and spread it evenly around the circumference of the seat. Do not get any compound on the valve stem. Insert the valve in its proper location in the cylinder and attach lapping handle (Tool No. 81513) to the valve stem.

Apply a light pressure on the lapping handle and lightly lap the valve and seat using an oscillating motion. Following the lapping operation wash the valve and cylinder thoroughly with unleaded gasoline, blow dry with compressed air and retest for leakage.

Valve tips are of uniform hardness, therefore, it is permissible to remove grooves or wear caused by the rocker arm roller, provided the amount of metal to be removed does not exceed the limit of tip refacing as determined by the valve limit gage. Break the sharp edge with a hand stone after grinding the tip. Recondition intake valves in the same manner as described for exhaust valves wherever the operations are applicable.

**ASSEMBLY** Lubricate the valve stems with engine oil. Put both valves in place in the cylinder and place the cylinder on the assembly block (Tool No. 80262). Install the lower valve spring washers around each valve guide. Place the inner, intermediate, and outer valve springs in place on the lower washers and the upper valve spring retainer washers on the top of the springs. Compress the valve springs using the valve spring compresser (Tool No. 81409) and install the valve locks. Make certain that the locks are properly located in the valve stem groove.

Temporarily install the rocker arms and check for interference between the under side of the rocker arms and upper valve spring washers or the outside diameter of the outer valve springs. If interference exists, use a valve spring washer which has a .010 inch undersize bore. This washer, when assembled on the valve and split locks, is seated .048 inch (1.22 mm) farther from the stem end of the valve than the standard washer, thus reducing the tendency for the rocker arms to interfere with the outer valve spring or valve spring upper washers.

Whenever a valve spring washer having an undersize bore is used, make the following check to insure that bottoming of the valve springs cannot occur: Measure the distance from the stem end of the valve to some convenient reference point on the cylinder, such as the rocker box cover mounting flange. Open the valve as far as possible, compressing the valve springs, and measure again the distance from the end of the valve to the same reference point. If the valve travel, which is the difference between these two measurements, is greater than .650 inch (16.5 mm) valve spring bottoming cannot occur. If the valve travel is less than .650 inch, it is highly probable that valve spring bottoming will occur during engine operation. In cases where the valve travel is found to be less than .650 inch, it is recommended that new valve springs be used in the assembly.

**PISTONS AND PISTON RINGS** If piston ring lands become worn sufficiently to require truing up, the piston ring grooves may be machined and fitted with rings of increased width. Piston rings for C9GC engines may be obtained in .002, .004, .006, .008, and .010 inch (0.51 mm, 0.101 mm, 0.152 mm, 0.204 mm, and 0.254 mm) oversize width for this purpose.

Whenever possible, an equal amount of material should be removed from each side of a ring groove. Under no circumstances should the depth of a piston ring groove be increased.

Extreme care should be taken to obtain a smooth fillet between the ring groove sides and the bottom of the ring grooves. Following the remachining of the piston ring

grooves, all sharp edges should be broken approximately 1/64 inch (0.397 mm) radius with the use of crocus cloth. Particular care should be taken to remove all sharp edges at oil holes.

It is recommended that piston rings be replaced at each overhaul period. Two important clearances must be obtained when installing new piston rings, the side clearance between the rings and ring grooves and the ring gap between the ends of the rings when in place in the cylinders in which they will operate.

The uniflow-type piston used in C9GC engines is provided with five piston ring grooves above the piston pin hole and one groove at the bottom of the piston skirt. These grooves are numbered from 1 to 6, starting with the groove nearest the head end of the piston as No. 1. The sides of the three top ring grooves are provided with a 15 degree taper, while the three bottom ring grooves have straight sides. The piston rings used in the three upper ring grooves have tapered sides which fit the tapered ring grooves in the piston and are also slightly tapered on the outside diameter. The three lower ring grooves are provided with three uniform width piston rings which are also provided with slight taper on their outside diameters. All piston rings are marked "TOP" on the side having the smaller outside diameter. The ring arrangement used on these pistons is as follows: Three rings with tapered sides are installed in piston ring grooves 1, 2, and 3, with the side marked "TOP" toward the head end of the piston. The fourth and fifth ring grooves are provided with uniform width piston rings which are also installed with the side marked "TOP" toward the head end of the piston. The bottom ring groove is provided with a uniform width compression ring which is installed in the inverted position in relation to the other rings, with the side marked "TOP" toward the open end of the piston.

To check the side clearance of wedge type piston rings proceed as follows:

Using a straight edge to hold the rings in position, measure the side clearance with a feeler gage adjacent to the straight edge. Clearances should be measured in four locations approximately 90 deg. apart. Pressure on the rings applied opposite the straight edge will place the rings in the proper position for measuring. Care must be taken to exert sufficient pressure to hold the rings against the straight edge and not to force the straight edge away from the surface to which the straight edge is applied. The straight edge may be held against either the piston ring lands or the piston skirt. Tolerances are given in the Table of Limits for each position. It is important that the proper limit be used. (Refer to the applicable Table of Limits for the correct side clearance.)

The side clearance of uniform width rings may be obtained by installing a ring in the ring groove of the piston on which it will operate. Insert a feeler gage between the ring and groove and measure the clearance at several points around the circumference of the piston. (Refer to the applicable Table of Limits.) Make certain that the groove is clean before checking this clearance, otherwise an accurate check of the clearance cannot be made. See figure 223. Oversize width piston rings are available which will permit obtaining the recommended side clearance. Do not grind or lap any piston ring to reduce its width.

**Fig. 223. Measuring Side Clearance of Uniflow Width Piston Ring**

If the side clearance, thus obtained for any piston ring is not within the limits specified in the applicable Table of Limits, replace that

ring with an oversize ring which will give the proper side clearance.

After the proper size ring has been selected for each ring groove, check it for gap. Care must be taken that each ring is kept in its proper position in relation to its location in the piston in which it belongs.

Check each ring for gap in the cylinder in which it is to operate or in a standard size barrel or gage. This practice should be followed to avoid improper gapping through the use of an oversize cylinder when checking the gap on standard size rings.

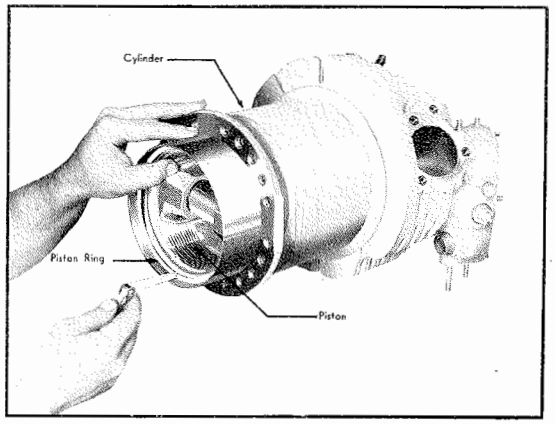



**Fig. 224. Measuring Piston Ring Gap**

To check for gap, remove the rings from the piston and slide the piston in the cylinder barrel until the end of the piston skirt is 2 or 3 inches (50.8 or 76.2 mm) from the end of the cylinder skirt. Place a ring in the barrel against the piston skirt and pull the piston so that the ring is about one inch from the edge of the cylinder skirt. This places the ring where the gap between the ends can easily be checked with a feeler gage and also insures the ring being located square with the cylinder bore. See figure 224. Consult the applicable Table of Limits for the desired gap. If the gap is greater than desired a ring oversize in diameter must be used; if the gap is not sufficient remove the ring from the cylinder and file the ends of the ring. Use caution when filing to keep the ends of the rings square. After obtaining the desired gap break the sharp edges at the filed surfaces.

Fit all the rings for one piston in the manner described, then reinstall them in their proper places on the piston before fitting the rings in the next cylinder.

Stamp the identification number on a new piston $1\frac{3}{16}$ inches (30.16 mm) from the outside edge and midway between the two valve head recesses.

# ROCKER ARMS, PUSH RODS AND PUSH ROD HOUSINGS

Refer to the sections entitled GENERAL REPAIR PROCEDURE and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**ROCKER ARMS** To remove a rocker arm roller hub or pin that requires replacement, grind one end of the pin flush with the face of the fork. Be careful not to mar or remove any metal from the fork. Center-punch the center of the ground end of the pin and with a suitable drill remove most of the metal that has been peened into the hole chamfer. Hold the rocker arm on a piece of stock provided with a hole large enough for the unground head of the pin to enter. Locate the arm so that the pin head is directly over the hole and drive out the pin, using a punch $\frac{15}{64}$ inch (5.95 mm) in diameter.

To install a new rocker arm roller or hub select a roller hub that will fit the fork in the rocker arm from .000 to .001 inch (.000 mm to 0.025 mm) tight. Hold the roller and hub in place in the arm and drive in the new pin until the ends extend an equal amount on each side of the rocker arm fork. Hold the rocker arm in one hand with the pin upright on an anvil. Strike the pin one hard blow with a heavy hammer first from one side, then a second blow from the opposite side. This will swell the pin to fit tight in the hub, then peen the ends of the pin with a light hammer to spread the pin metal into the chamfer in the pin hole on each side of the rocker arm fork.

Rivet the ends using a rivet setter. The fork in the arm will not be closed up by riveting as the roller hub is slightly wider than the roller.

Remove all burrs or nicks from the screw driver slots of the adjusting screw and dress the threads if necessary. Clean the cup with crocus cloth held on an old push rod ball end. This operation is best done by securing the crocus cloth over the push rod ball end and chucking the push rod in a lathe or drill press. If the adjusting screw is screwed into a discarded rocker arm, it can easily be held against the revolving crocus cloth covered push rod ball end. After this operation, clean the oil hole and remove sharp edges.

If the clamp screws are not to be replaced, stone the heads to remove all burrs and smooth the threads if necessary.

Remove any nicks or burrs on the rocker arm bolts, nuts, or outside surfaces of the spherical washers, but do not disturb the spherical seat surfaces.

Install the rocker arm bearing by first heating the rocker arm in an oil bath at a temperature of 250 deg. F. Chill the bearing in dry ice and alcohol or gasoline. Use an arbor press and the plug and collar (Tool No. 83444) to install the bearing into the rocker arm.

Screw the adjusting screws into the rocker arms until the shoulders on the screws contact the bottom face of the rocker arms. Place new lockwashers on the clamp screws and insert the screws in the rocker arms. Do not tighten the clamp screws at this time.

**PUSH RODS AND PUSH ROD HOUSINGS** Roll push rods which are slightly bent and are to be straightened on a flat plate to determine the high spot and tap back to proper shape with a light rawhide mallet. Continue this operation on each rod until it is straight as determined by the use of V-blocks and dial indicator. Check the ball ends for tightness and tubes for cracks after straightening.

Clean the ball ends with crocus cloth in the same manner as described in the cleaning of the adjusting screws except that in this case a discarded adjusting screw is chucked in the lathe or drill press.

Do not attempt to renew push rod ball ends.

Remove dents from the push rod housings by tapping them out when the housing is placed on a properly fitting mandrel.

## INTAKE PIPES AND AIR DEFLECTORS

Refer to the sections entitled REPAIR PROCEDURE and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**INTAKE PIPES** Straighten intake pipes that are not too badly dented by placing the pipe on a mandrel of the proper size and shape and by hammering out the dents with a light wood or fiber mallet. Use extreme care when hammering not to reduce the wall thickness of the pipes.

Remove any nicks or burrs from the attaching flange with a fine file. Smooth the finished surfaces with crocus cloth.

**AIR DEFLECTORS** Straighten cylinder air deflectors which are bent or dented. Small cracks may be repaired by welding.

Replace any loose rivets using a rivet setter.

Replace any screws or nuts having damaged threads.

Re-enamel the intake pipes or air deflectors as necessary.

## IGNITION WIRING MANIFOLD ASSEMBLY

Refer to the sections entitled REPAIR PROCEDURE and GENERAL ASSEMBLY PROCEDURE, included at the beginning of this chapter.

**REPAIR** Repair cracks in the manifold ring by silver soldering or brazing. Dress up any damaged threads and remove all dents from the ring and outlets and replate if necessary. Remove any nicks or burrs from the magneto outlets or elbow flanges using a fine file. Replace any flexible conduits having broken braid, or coupling nuts with mutilated threads. Renew the ignition contact sleeve and spring assembly if the

spring is loose or broken or if the sleeve is cracked. Replace the spark plug terminal elbows if cracked or if the coupling nuts are cracked or the threads mutilated. Stone any burrs from the edges of the coupling nuts. Clamps or brackets that are cracked or broken should be replaced. Discard the ignition wire and all rubber washers and packing.

**ASSEMBLY** Before reassembling the ignition harness install new ignition cables in the manifold. Cut the ignition cables to the lengths specified in the following table:

After cutting new ignition wire to size for installation in the manifold, each wire should be tested for leaks or defective insulation. This test may be accomplished with any suitable high tension electrical equipment such as a portable booster magneto.

The use of powdered talc or powdered mica is recommended as an aid when feeding the wires through the manifold, the talc or mica acting as a lubricant will allow the wires to slide more easily over each other. Apply the talc or mica to each wire before entering it in the manifold as follows: Place some talc or mica in a receptacle and while holding a portion of the wire submerged with the fingers of one hand draw the complete length of the wire through the powder with the other hand. As each cable is treated with powdered material feed it into the manifold in the numerical order shown on the wiring assembly diagram. See figure 225.

Each half of the manifold ring should be wired separately starting with the right half (facing the rear of the manifold).

For example the first wire to be installed is F 5 or that one leading from No. 3 block to the front plug of No. 5 cylinder. The second wire is R 5 or that one leading from block No. 3 to the rear plug of No. 5 cylinder. F 4 and R 4 wires follow next and this procedure should be continued according to figure No. 225 until all wires are in place. Push the wires through the large opening in the manifold marked "R". As the installation of each wire is completed, install a brass washer on the magneto end using Tool No. 803829, denoting the position of the wire in the distributor block.

Exercise extreme care while wiring the manifold to avoid abrasion or other damage

| Right Hand Magneto (Block Numbers) | Front Spark Plugs (Cylinder Numbers) | Order of Wiring Manifold | Wire Length (Inches) |
|---|---|---|---|
| 1 | 1 | 9 | 76 |
| 2 | 3 | 5 | 85 |
| 3 | 5 | 1 | 98 |
| 4 | 7 | 12 | 90 |
| 5 | 9 | 17 | 80 |
| 6 | 2 | 8 | 80 |
| 7 | 4 | 3 | 90 |
| 8 | 6 | 10 | 98 |
| 9 | 8 | 14 | 95 |
| **Left Hand Magneto (Block Numbers)** | **Rear Spark Plugs (Cylinder Numbers)** | **Order of Wiring Manifold** | **Wire Length (Inches)** |
| 1 | 1 | 18 | 85 |
| 2 | 3 | 6 | 96 |
| 3 | 5 | 2 | 111 |
| 4 | 7 | 13 | 103 |
| 5 | 9 | 16 | 94 |
| 6 | 2 | 7 | 94 |
| 7 | 4 | 4 | 103 |
| 8 | 6 | 11 | 111 |
| 9 | 8 | 15 | 96 |

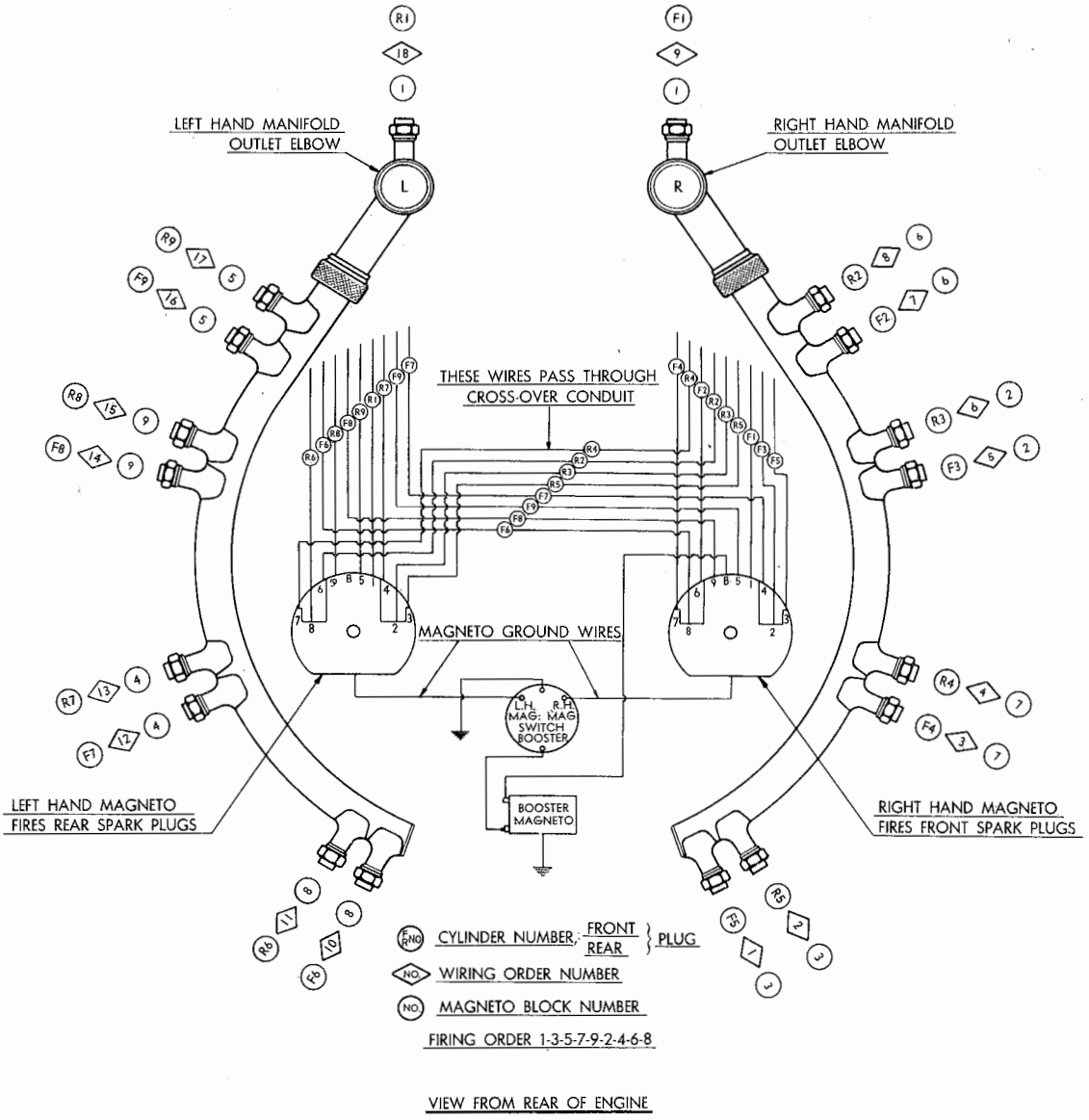

LEFT HAND MANIFOLD OUTLET ELBOW
RIGHT HAND MANIFOLD OUTLET ELBOW
THESE WIRES PASS THROUGH CROSS-OVER CONDUIT
MAGNETO GROUND WIRES
L.H. MAG. SWITCH
R.H. MAG. BOOSTER
BOOSTER MAGNETO
LEFT HAND MAGNETO FIRES REAR SPARK PLUGS
RIGHT HAND MAGNETO FIRES FRONT SPARK PLUGS
CYLINDER NUMBER, FRONT / REAR } PLUG
WIRING ORDER NUMBER
MAGNETO BLOCK NUMBER
FIRING ORDER 1-3-5-7-9-2-4-6-8
VIEW FROM REAR OF ENGINE

**Fig. 225. Ignition Wire Diagram**

to the ignition wires. A weak spot or break in the insulation will result in subsequent failure.

In the event new shielding braid is necessary, replace with a new braid and new couplings.

Screw the magneto outlet adapter front flange on the long conduit and push the wires with markers through the conduit. Attach the long conduit to the right half of the manifold ring. Determine which wires pass through the magneto outlet adapter rear elbow for attachment to the left hand magneto and which pass through the bottom of the outlet adapter for attachment to the right hand magneto. See figure 225. Insert the wires through their respective locations and attach the magneto outlet adapter front flange, adapter outlet, and rear elbow together, using the long through bolts. The parting surfaces on these parts should be coated with Dow Corning No. 4, Parker Sealube, or Titeseal compound.

Wire the left half of the manifold in the same manner, starting with ignition wire No. 10 and passing out through the outlet marked "L". See figure 225.

Install the cross-over tube, inserting the wires through the tube and out their respective outlets.

When all the wires are properly placed and protrude through the magneto adapter outlets, it will be necessary to trim the wires in accordance with the following table:

| Left Hand Magneto Block Wire Number | *Trim to Length (Inches) | Right Hand Magneto Block Wire Number |
|---|---|---|
| 1 | 6 | 1 |
| 2 | 5 | 2 |
| 3 | 4-½ | 3 |
| 4 | 4 | 4 |
| 5 | 4 | 5 |
| 6 | 4 | 6 |
| 7 | 4-½ | 7 |
| 8 | 5 | 8 |
| 9 | 6 | 9 |

*This length to be measured from magneto adapter outlet lower parting surface to end of wire.

Place a new rubber washer over the spark plug end of each cable and slide it down into the nipple on the ignition manifold. Install the spark plug terminal conduit over the ignition cable and secure to the manifold by tightening the knurled coupling nut. Allow sufficient cable to protrude from the end of the conduit to install the spark plug terminal elbow and terminal sleeve. Install a rubber washer and the elbow on the ignition cable and secure the elbow to the conduit by tightening the knurled nut. It is recommended that Dow Corning No. 4 be inserted in the elbow at this time to prevent condensation from forming thus causing subsequent failure of the cable insulation. To accomplish this, use an alemite type pressure gun with a suitable adapter to fit the terminal nut. Insert the end of the ignition cable into the adapter and screw the spark plug terminal nut down tight on the adapter. Inject Dow Corning No. 4 into the spark plug elbow by means of the pressure gun. Care must be taken to prevent the compound from forcing the ignition cable back into the spark plug elbow. After filling the spark plug elbow, remove the pressure gun and wipe off any excess compound on the ignition cable with a clean lintless cloth. Since the compound has an adhesive quality, care must be taken that coated surfaces and the compound are kept clean of foreign particles and dirt. Remove about ¼ inch of the insulating material from the end of the spark plug cable and insert the end of the exposed wire through the brass washer in the insulating sleeve. The stripped end of the cable should protrude through the hole in the washer at the base of the contact spring about ⅛ of an inch. Fan the strands of cable around the washer and press the strands securely into

position over the end of the contact washer nipple by means of a short copper tube (⅛ inch I.D.). Install a bakelite contact protector over each terminal.

Remove ½ inch of the insulation from the magneto end of each wire. Separate the strands of wire, space them evenly and fold back over the insulation. Install the thin brass washer over the end of the wire and secure it in place using the special pliers, Tool No. 803828. See figures 226 and 227.

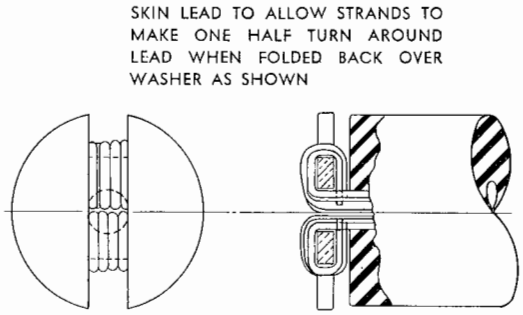

SKIN LEAD TO ALLOW STRANDS TO MAKE ONE HALF TURN AROUND LEAD WHEN FOLDED BACK OVER WASHER AS SHOWN
VIEW SHOWING ATTACHMENT OF WASHER MAGNETO END OF CABLE

**Fig. 226. Method of Installing Washer on Ignition Cable**

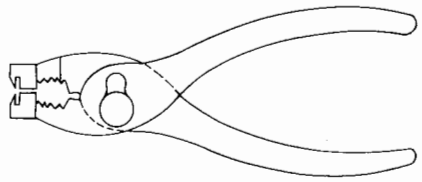


**Fig. 227. Special Pliers Used to Install Washer on Ignition Cable**

Apply a thin coating of Dow Corning No. 4 on the surface of each ignition cable for a distance equivalent to the depths of the respective terminal wells in the distributor blocks. Insert the ignition cables numerically in their respective positions in the distributor blocks. Insert and tighten the piercing screws which secure the wires in the blocks. Remove any excess compound with a clean lintless cloth. Install the magneto block covers, and secure each with the two clamping cap screws and nuts, and two lower retaining cap screws. If the wires are too long, feed them back into the manifold as much as possible so that the extra length may be used for future repairs, if this should be necessary.

Install the coil cover on the magneto and secure it at the breaker end with the two screws. Secure the coil cover and radio shield to the front end plate with the six long screws. All the coil cover screws should carry lockwashers.

Strip back the insulation from the ground wire for about 3/16 inch (4.76 mm) and twist the wire slightly. Install the insulating rubber washer and insert the wire through the brass contact button. Pull the insulating sleeve and rubber washer away from the contact and fan the wire out slightly. Solder the wire to the contact button and file the solder flush with the end of the contact.

Insert the round terminal into the sleeve in the magneto breaker housing and secure the assembly with the knurled nut. Lock the knurled nut with the spring wire lock ring.

Tighten the knurled coupling nuts securing the radio shielding at both ends of the "Y" terminal or install the cap if the terminal is not used.

After the ignition manifold assembly is complete, check each wire for proper location, leaks and faulty insulation with a portable magneto. See figure 228 for proper location of the wires. Install bakelite contact protectors on each spark plug elbow and secure by means of the spark plug attaching nut.

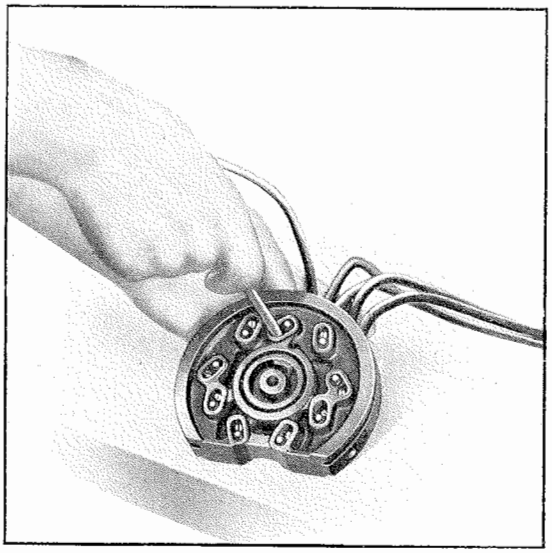


**Fig. 228. Attaching Ignition Wire in Distributor Block**

CHAPTER VI

# FINAL ASSEMBLY AND TIMING

DURING the assembly of an engine there are certain operations which should be witnessed or inspected by the shop foreman or inspector. The ENGINE ASSEMBLY INSPECTION FORM lists these operations and in addition includes items to be checked by the inspector. The inspector should initial or sign his name at each item after the operation has been witnessed or the inspection made.

Refer to INSPECTION FORMS in the section in the Appendix entitled INSPECTION FORMS.

When oiling the various parts during their assembly use the same grade of engine lubricating oil that is used for the regular operation of the engine unless special instructions are given for some other lubricant to be used. Refer to the section GENERAL ASSEMBLY PROCEDURE of the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES for information covering subjects important when assembling engines.

## SUPERCHARGE FRONT HOUSING AND CRANKCASE REAR MAIN SECTION

**SUPERCHARGER FRONT HOUSING** With the disassembly and assembly stand engine mount plate turned to its lowest horizontal position in the stand, place the supercharger front housing on the plate with the open portion facing the plate and the top of the housing toward the cut-out portion of the plate. Secure the housing to the plate with the long bolts, inserted from the bottom of he plate, fla washers, and nuts.

**CRANKCASE REAR MAIN SECTION** If the crankcase rear main section was removed from the supercharger front housing, install it at this time. Secure the crankcase section to the supercharger front housing with the eighteen cap screws and spherical seat washers inserted from the rear of the supercharger front housing. Tighten the cap screws and lockwire in pairs. NOTE: Make certain that the rubber oil seal is placed between these two sections at assembly.

## CRANKSHAFT, MASTER AND ARTICULATED ROD ASSEMBLY

Install a lifting eye in the crankshaft front extension, screwing it on the reduction driving gear retaining nut threads. Lower the crankshaft assembly carefully onto the rear main section, placing the master rod in the No. 1 cylinder pad location and the articulated rods in their respective locations. See figure 229. When the assembly is in its proper location, remove the lifting eye and install the crankshaft front end protector (Tool No. 800986).

Use extreme care when lowering the assembly not to damage the outer race of the rear main bearing. Refer to the applicable Table of Limits for proper fit of the bearing in the retainer.

**CRANKSHAFT FRONT MAIN BEARING INNER RACE** Heat the inner race of the crankshaft front main bearing in an oil bath at 225 deg. F. (108 deg. C.) for 10 minutes. Install the race on the crankshaft front extension tapping the race lightly with a fiber drift while cooling to insure a tight fit against the shoulder of the crankshaft.

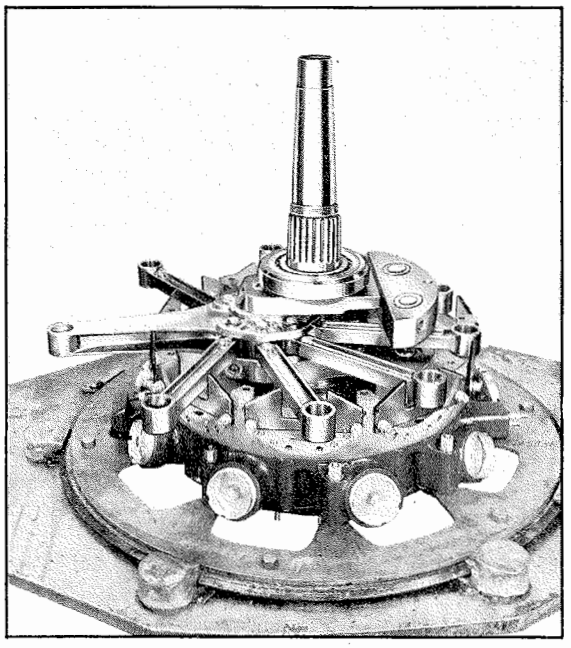


**Fig. 229. Crankshaft Assembled to Crankcase Rear Main Section**

# CRANKCASE FRONT MAIN SECTION

**CRANKCASE FRONT MAIN SECTION**

Place the front half of the crankcase main section on two wooden blocks so that the section is supported at opposite points on the crankcase front section parting surface. Insure that the cam drive gears are free of the blocks. Note that the bearing outer race is marked "PROPELLER END" for proper installation. Assemble the outer race and rollers in the bearing retainer and, if necessary, tap them into position with a fiber drift. However, if the outer race is loose in the retainer, assemble the rollers and outer race on the front race which is installed on the crankshaft.

Turn the crankcase front main section over so that it rests on the crankcase rear main section parting surface. Install the reduction driving gear spacer and ring assembly. Tap the spacer in place against the front main bearing outer race.

Coat the mating surfaces of both the front and rear main crankcase sections with Tite-seal, or its equivalent, and install the nine short rubber seals at these mating surfaces on the crankcase rear half. Make certain that the seals are in their proper position before continuing the assembly. See figure 230.

Install the new oil seal rings over the oil passage dowels. Install the crankcase front

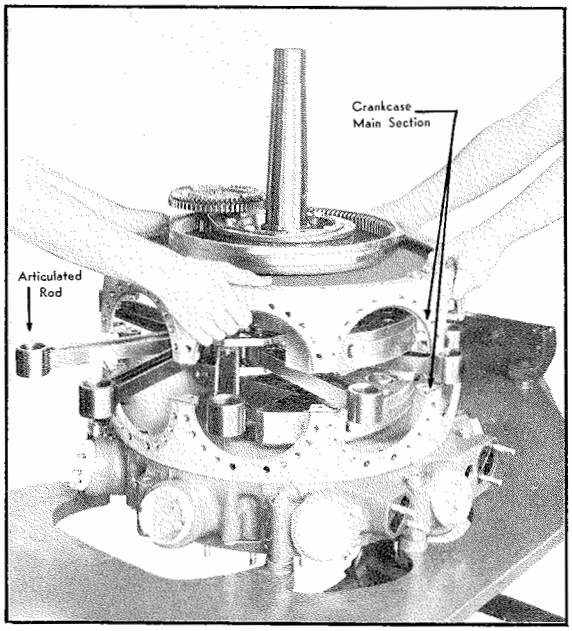



**Fig. 230. Installing Crankcase Front Main Section**

main section and cam drive gear assembly over the crankshaft front extension, locating the proper cylinder pads and insuring that the oil dowels are lined up. Make certain that the rings are in their proper position. Insert the crankcase main section internal attaching bolts and nuts. Using a torque wrench, tighten the nuts to the required torque value and insert cotter pins. (Refer to the applicable Table of Limits.) See figure 231. After tighten-

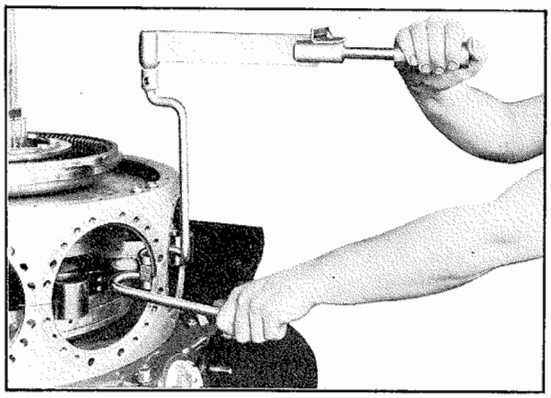


**Fig. 231. Tightening Crankcase Internal Attaching Nuts**

ing the main crankcase attaching bolts and nuts, cut off the seals flush with the side of the crankcase.

**REDUCTION DRIVING GEAR** Turn the intermediate cam drive gear until the timing marks on the pinion gear line up with similar marks on the cam. In this position the timing marks on the teeth of the intermediate cam drive gear nearest the crankshaft should be directly in line with the center line of the crankshaft. See figure 232.

Turn the crankshaft until the reduction driving gear locating pin is 90 deg. counterclockwise from the timing marks on the intermediate cam drive gear.

Heat the reduction driving gear in an oil bath at 375 deg. F. (190 deg. C.) to 400 deg. F. (204 deg. C.) for 30 minutes. Coat the crankshaft reduction driving gear splines with Lubriplate 130 A, or its equivalent. Install the reduction driving gear on the crankshaft splines, locating the blind spline in the reduction driving gear over the pin in the crankshaft front extension splines, which is located 90 deg. counterclockwise from the timing mark on the intermediate cam drive gear. CAUTION: In the event the reduction driving gear seizes on the shaft during installation, do not attempt to remove it while hot. Allow the parts to cool to room temperature and remove the gear using the puller (Tool No. 84857) and one of the following adapters: (Tool No. 84724, 84858, and 84857). This procedure will prevent scoring of the shaft and reduction driving gear.

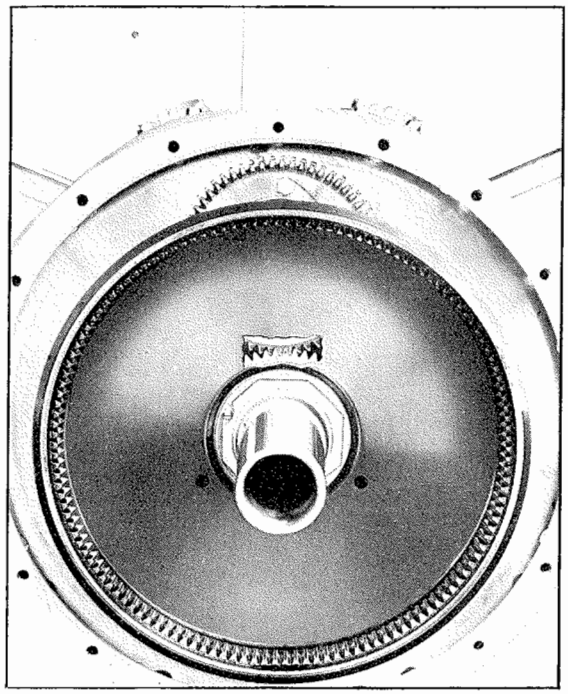


**Fig. 232. Timing Cam Drive Gear and Reduction Drive Gear**

Install the special nitrided steel ring over the crankshaft front extension and install the reduction driving gear retaining nut. To prevent the crankshaft from turning, install a fiber drift in the piston pin eye of the master rod and turn the crankshaft so that the drift rests against the cylinder pad. Tighten the retaining nut, striking the shank of the wrench (Tool No. 82670) with a lead hammer.

After the reduction driving gear has cooled, remove the retaining nut and the nitrided steel ring. Install the crankshaft lifting eye (Tool No. 82151) and check the end play of the crankshaft. Place the base of the indicator dial on the crankcase main front section and

the indicator on the reduction driving gear. Raise and lower the crankshaft by means of a chain hoist and determine the existing end clearance. Refer to the applicable Table of Limits for proper end clearance. Remove the crankshaft lifting eye and reinstall the retaining nut. Tighten it as previously described and lock it securely with the lock screw.

## CRANKCASE FRONT SECTION

Before installing the crankcase front section, install the large oil seal packing ring in its groove in the crankcase front section.

Install new oil seals over the oil passage dowels.

Coat the crankshaft front extension with clean engine oil. Attach a lifting eye and chain hoist to the propeller shaft and lower the crankcase front section and propeller shaft assembly over the crankshaft front extension. Use extreme care not to damage the propeller shaft bushings. Insure that the oil passage dowels line up with the mating holes in the crankcase front section. It is desirable to remove the cover plate from the governor mount pad and turn the governor drive gear to insure proper meshing of the gears. Secure the crankcase front section to the crankcase front main section with plain washers and cap screws. Insure that the four ignition harness manifold mounting brackets are located in their proper position, on the raised cap screw bosses. These brackets should be secured with the long crankcase front section attaching cap screws. Tighten all the cap screws and lockwire in pairs.

The above procedure applies to engines of both .5625 (16:9) and .666 (3:2) ratio reduction but the .666 (3:2) reduction requires, in addition, that the propeller shaft must be timed in relation to the crankshaft.

Turn the crankshaft until the master rod is at the top center position of its stroke as set by the top center indicator (Tool No. 80932). Do not move the crankshaft from this position.

Place the pointer (Tool No. 800157) on the propeller shaft so that the wide spline space in the tool encloses splines No. 1 and No. 16.

Turn the propeller shaft until the pointer (Tool No. 800157) indexes with the center of the timing mark on the front section flange.

Move the front section into place, engaging the pinions with the reduction driving gear. If engagement is not possible with the propeller shaft in this position, turn the propeller shaft very lightly to obtain tooth meshing in the nearest tooth location.

Check the top center indicator (Tool No. 80932) to make certain that the crankshaft has not been turned. Check the pointer (Tool No. 800157) to make certain that it indexes within the limits of the timing mark on the front section flange. This mark is made wide enough to accommodate the permissible error.

Remove the pointer from the propeller shaft and complete the installation of the front section as described above. Remove the lifting eye.

**BREATHER TUBE ASSEMBLY** Place the breather tube rear gasket inside the propeller shaft over the front bushing. Lubricate the bearing surfaces of the breather tube with clean engine oil, and install the breather tube. See to it that the front flange of the breather tube seats squarely on the rear gasket and propeller shaft front bushing. Place the front gasket over the breather tube flange, and install the adapter or plug, whichever is used. Install the breather tube retaining nut inside the propeller shaft, and tighten with the special plug wrench. Place the crankshaft breather screen over the retaining nut, and secure it with plain washers, screws, and lock wire. Better alignment of the screw holes in the screen and in the retainer nut may be obtained by inverting the screen. Install the propeller shaft protecting cap.

**VALVE TAPPET GUIDES** Install new gaskets over each valve tappet guide mount pad attaching studs. Install the valve tappet guide assemblies and secure with plain washers, nuts, and palnuts. Note that each tappet guide is etched to identify its proper position.

# CYLINDERS AND PISTONS

Install the engine turning hub (Tool No. 82284) with handles (Tool No. 80292) on the propeller shaft. Rotate the propeller shaft until the master rod in No. 1 cylinder is at the top of its stroke.

Install the piston pin retainers in the rear side of each piston before assembling the pistons on the rods. Use installing tool (Tool No. 84861) and adapter (Tool No. 800197) for installation for these coil spring type piston pin retainers.

Make sure the retainers are properly seated in the retainer grooves.

To install a piston pin retainer in the groove on the rear side of the piston, place the retainer spring on the installing tool (Tool No. 84861) with the spring joint approximately 90 deg. either side of the cut-out in the tool. See figure 233. Install a piston pin in the

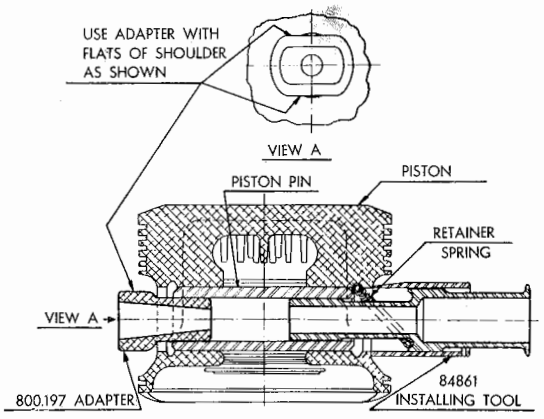



**Fig. 233. Installing Rear Piston Pin Retainer**

piston with the large diameter of the chamfer on the pin flush with the inner edge of the groove in the piston. Insert the end of the installing tool in the piston pin from the side of the piston in which the retainer is to be installed, with the cut-out surface of the tool at the top of the piston pin hole. While performing this operation locate the top section of the retainer spring in the top section of the groove. Install the adapter (Tool No. 800197) in the opposite end of the piston pin and, while holding the pin in position with one hand, apply pressure on the installing tool with the other and force the retainer into its seat in the retainer groove. See figure 234. Remove the installing tools.

Lubricate the master rod piston pin bushing and piston pin with engine oil. Start the piston pin into the front side of the piston, place

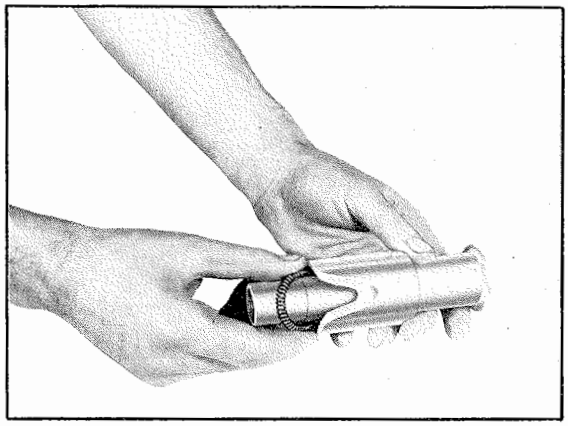


**Fig. 234. Installing Piston Pin Retainer in Installing Tool**

it in position on the rod and push the pin through the bushing and opposite side of the piston until it bottoms against the rear retainer.

Install the front piston pin retainer in the same manner as described for installation of the rear retainer except that the adapter is not required since the rear retainer prevents the pin from slipping through the piston. See figure 235.

Lubricate the barrel of No. 1 cylinder with engine oil and install a new rubber oil seal ring below the hold-down flange. Check that all piston rings are properly installed and set the gaps so that they are equally spaced (staggered) around the piston. Check to insure that both piston pin retainers are installed and seated correctly. Coat the piston and piston pin freely with castor oil.

Remove the connecting rod protector from the crankcase cylinder mounting pad. Make sure that the surfaces of the cylinder flange and crankcase mounting flange are clean and free from enamel. Compress the upper five rings with the clamp (Tool No. 80440) and slide the cylinder over these rings. Move the clamp to compress the bottom piston ring and

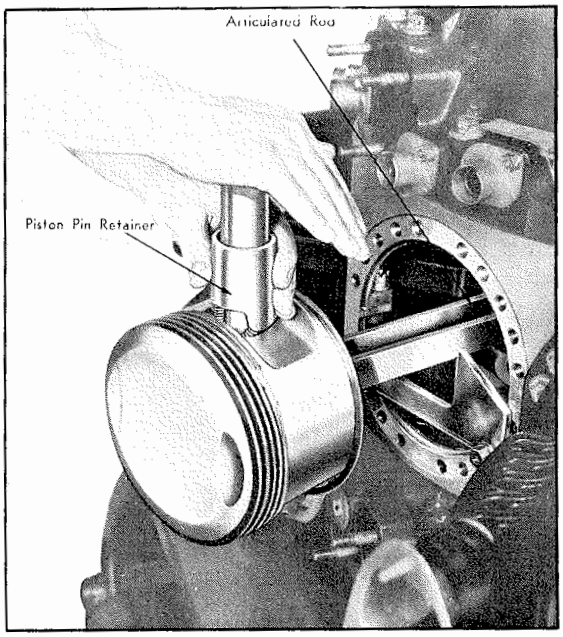



**Fig. 235. Installing Front Piston Pin Retainer**

slide the cylinder over the entire piston onto the crankcase mounting pad. See figure 236.

The cylinders are secured to the crankcase by means of spherical seat washers and cap screws. When installing these cap screws, carefully apply a very small amount of Glyptal, or its equivalent, to the cap screw threads

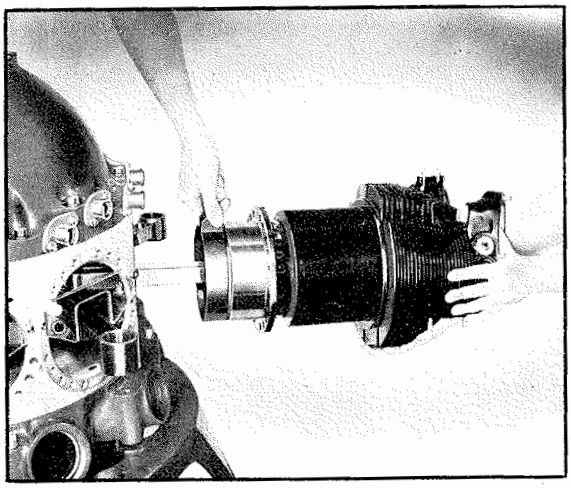


**Fig. 236. Installing Cylinder on Crankcase**

to prevent oil leakage at these points. When a cylinder has been installed, locate it on the cylinder mounting pad immediately by tightening the two special locating cap screws (Tool No. 84501). See figure 237.

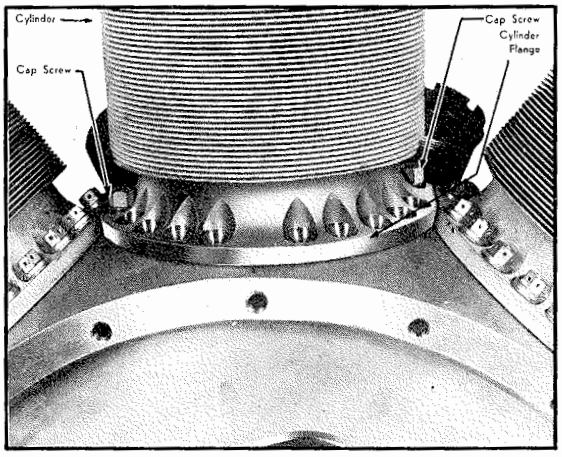



**Fig. 237. Locating Cylinder**

Install these two cap screws in two cylinder holes on opposite sides of the cylinder. Tighten these cap screws evenly and to the proper torque value using wrench (Tool No. 82750) and torque indicating handle (Tool No. 84922). (Refer to the applicable Table of Limits.)

Install a spherical seat washer on each cap screw and install the cap screw immediately after applying Glyptal, or its equivalent, to the threads. Install all the cap screws and tighten to the proper torque with the above mentioned wrench and handle. (Refer to the applicable Table of Limits for the proper torque value.) Tighten two cap screws approximately 90 deg. from the locating cap screws first and then those approximately 45 deg. from the first, repeating this procedure

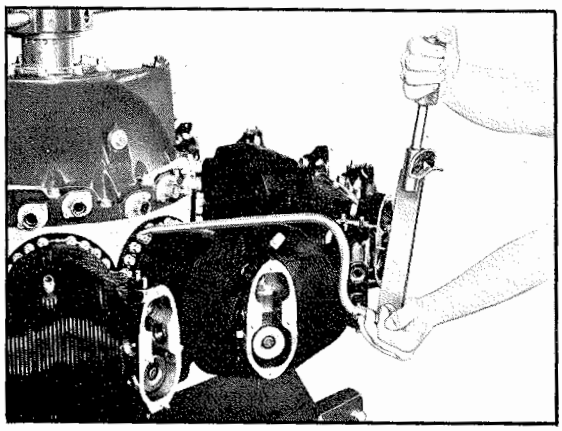


**Fig. 238. Installing Cylinder Hold Down Cap Screw**

until all the cap screws have been tightened. Remove the two locating cap screws and replace with the standard spherical washers and cap screws and tighten to the specified torque value. See figure 238.

Install cylinders No. 2 and 9 in the same manner. Turn the crankshaft until No. 4 cylinder is at top dead center and install cylinders No. 3, 4, and 5. Follow the same procedure as above for locating and tightening. Turn the crankshaft until No. 7 cylinder is at top center and install cylinders No. 6, 7, and 8.

Lockwire the cap screws in groups of five. Twist the wire between each nut and twist the ends together securely.

# VALVE TAPPET BALL SOCKETS, PUSH ROD HOUSINGS, PUSH RODS, ROCKER ARMS, AND ROCKER BOX COVERS

**VALVE TAPPET BALL SOCKETS** Insert each valve tappet spring and valve tappet ball socket into its respective hollow tappet, insuring that all new parts are thoroughly coated with engine oil before assembly.

**PUSH ROD HOUSINGS** Install a new short hose connection and one clamp on the rocker box end of the push rod housing. The rocker box end of the push rod housing may be identified by the location of the beading which is approximately ⅜ inch (9.52 mm) from the end. Install new long hose connections and two clamps per connection on the crankcase end of the housing. The beading at this end of the housing is directly on the end.

With the hose connections and clamps assembled on the push rod housing, install the housing on the engine, pushing it all the way onto its rocker arm hose connection and tighten the clamp. Slide the crankcase end hose connection over the tappet guide and tighten both clamps.

**PUSH RODS AND ROCKER ARMS** The number of times it will be necessary to turn the crankshaft when installing push rods and rocker arms can be reduced to two complete revolutions if the rocker arms are installed in accordance with the engine firing order.

Screw the valve clearance adjusting screw into each rocker arm until the flange in the screw bottoms in the rocker arm.

Oil the push rod ball ends with clean engine lubricating oil and insert in the push rod housing through the rocker box. Lubricate rocker arms and bolts with clean engine oil. Install the rocker arm and insert the rocker bolt through its hub. Make sure that the spherical seat washers are installed at each end of the through bolt. The bolt should be installed with its head facing the centerline of the cylinder head.

Before tightening the castellated nut on the rocker bolt, check the end clearance between the bearing inner race and the rocker box.

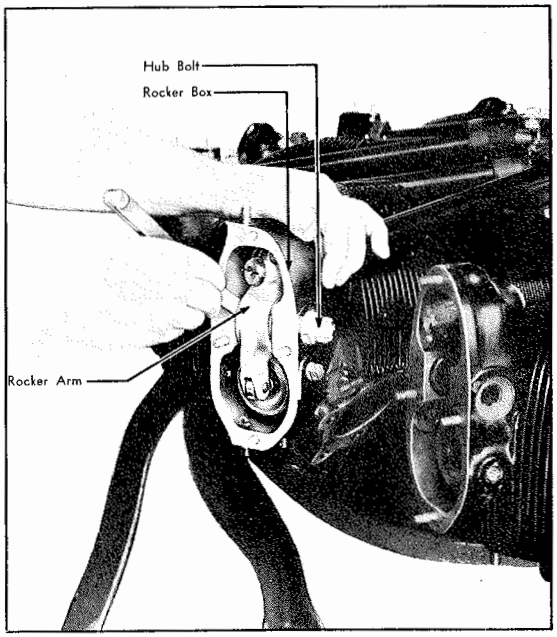



**Fig. 239. Checking End Clearance Between Rocker Arm Bearing Inner Race and Rocker Box**

If it is over the limit specified in the applicable Table of Limits, remove the bolt and install a shim to take up the excess. It is important that the correct clearance be obtained at this location to prevent damaging the rocker box due to excessive clamping. See figure 239.

Tighten the rocker bolt nut to the torque value as specified in the applicable Table of Limits using the torque wrench handle (Tool No. 84922) and a socket. See figure 240. If

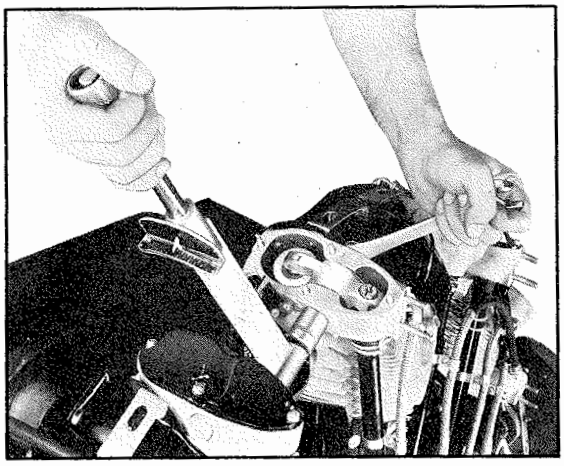


**Fig. 240. Tightening Rocker Hub Bolt Nut**

it is necessary to exceed the recommended torque value to line up the cotter pin hole, select another washer and nut. Insert a cotter pin which fits the hole properly and secure it by bending one end against a flat on the nut and the other end over the end of the bolt.

When installing rocker arms be extremely careful not to install the intake rocker arm in the exhaust rocker box or vice versa.

**ADJUSTMENT OF VALVE CLEARANCES** To adjust the clearance between the valve stem and rocker arm roller, turn the crankshaft until the piston in No. 1 cylinder is on top center on the compression stroke. In this position the valve tappet rollers are at their lowest point of travel on the cam ring between the cam lobes, which places both valves in the fully closed position. To check that No. 1 cylinder is on its firing stroke, test the two adjacent valves, No. 2 exhaust and No. 9 intake. When the intake valve to the left is approximately ½ open and the exhaust valve on the right is approximately ½ closed, viewed from the rear, the piston in the cylinder being checked is on top center on the firing stroke, with both valves closed. See figure 241.

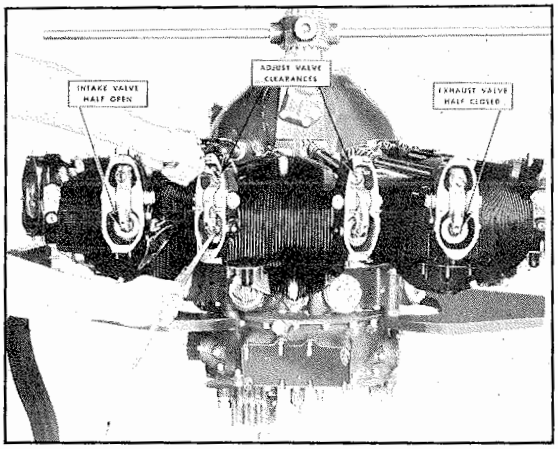



**Fig. 241. Adjusting Valve Clearance**

Screw in the adjusting screw of each rocker arm of cylinder No. 1 until the rocker roller bears against the valve stem tip and the valve tappet spring is fully compressed. Tap the adjusting screw end of the rocker arm lightly to insure that the push rod ball socket is properly seated. Exert constant pressure on the push rod end of the rocker arm while turning the adjusting screw and inserting the feeler gage to overcome the tension of the valve tappet spring. Turn the adjusting screw in the opposite direction until a .010 inch clearance exists between the rocker arm roller and the valve stem tip. See figure 241 for details of adjusting the clearance. Tighten the adjusting screw lock screw using wrench (Tool No. 81900) and recheck the clearance. CAUTION: Each valve clearance adjusting screw is marked on its outer face in line with the three radially drilled holes in the screw. See figure 242. When adjusting the valve clearance insure that none of the drilled holes line up with the split in the rocker arm. Insure that the hole is at least 3/32 inch (2.38 mm) from the nearest edge of the split in the rocker arm. If this condition is encountered after the .010 inch clearance has been set, it is permissible to unscrew the adjusting screw, in the direction to increase the valve clear-

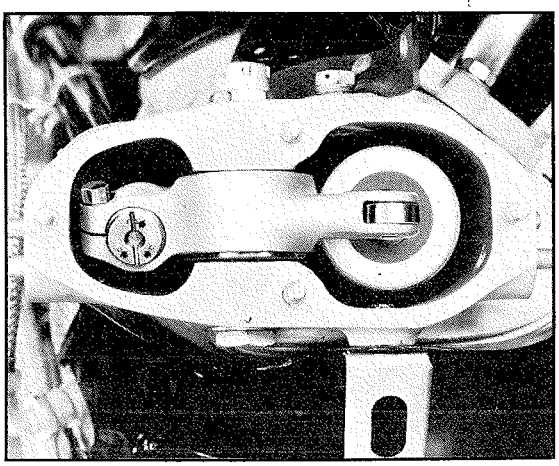


**Fig. 242. Location of Indexing Marks on Adjusting Screw**

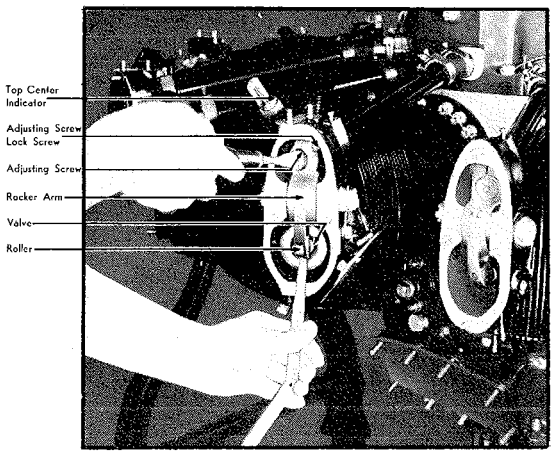



**Fig. 243. Adjusting Valve Clearance Showing Use of Top Center Indicator**

ance, the least amount necessary to overcome the above condition.

Turn the propeller shaft in the direction of normal rotation until the valve mechanism of cylinder No. 3 (the next cylinder to fire) is in the proper position for adjustment of the valve clearance. Insure that the relative positions of the adjacent valves are similar to those described above. Adjust the valve clearance of cylinder No. 3 as described in the foregoing procedure and continue with each cylinder in the normal direction of rotation and in the firing order, as follows: Cylinders No. 1, 3, 5, 7, 9, 2, 4, 6, and 8.

An alternate, less rapid method for determining when a piston is on top center is by the use of a top center indicator. Install top center indicator (Tool No. 80932) in the front spark plug insert of No. 1 cylinder and rotate the propeller shaft in the normal direction of rotation until the piston is at approximately top center of the firing stroke. Move the propeller shaft back and forth, noting the variations to each side of the center. Tap the shaft back to the point where the indicator shows the piston to be stopped or changing direction of travel. See figure 243. Adjust the valve clearances of the valves in No. 1 cylinder by the method previously described. Following the regular firing order, turn the crankshaft until the next cylinder to fire is on top center and adjust the clearances of the valves in this cylinder in the same way. Continue in the same manner until all valve clearances have been adjusted.

In all cases, the top center position of No. 1 piston on the compression stroke may be checked by inspection of the timing marks on the reduction driving gear. To do this, remove the inspection plug in the crankcase front section and insure that the indexing grooves cut in the housing are opposite "0" on the reduction driving gear timing scale. See figure 244.

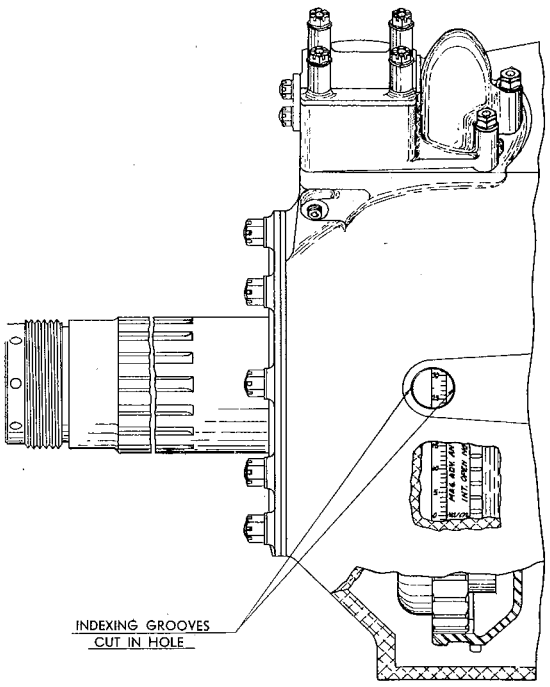



**Fig. 244. Timing Marks on Reduction Drive Gear**

**ROCKER BOX COVERS** After the valve clearances have been properly adjusted, and with the crankshaft in a horizontal position, place gaskets over the studs on all rocker boxes except the master rod cylinder. Pour ½ pint of engine lubricating oil in the rocker boxes above the horizontal center line. Install rocker box covers on those oiled rocker boxes securing them with flat washers, nuts and palnuts.

Rotate the engine to bring the bottom cylinders on top, pour lubricating oil in remaining rocker boxes and install covers.

## SUPERCHARGER REAR HOUSING AND COVER

Turn the engine on the assembly stand so that the propeller shaft points straight downward.

Place lifting eye (Tool No. 83863) on the starter mounting pad of the supercharger rear housing cover and secure it with the starter retaining nuts. Attach a chain hoist to the litfing eye and raise the rear section from its assembly stand until the impeller shaft front oil seal sleeve with rings is accessible.

Coat the impeller shaft front oil seal ring assembly with engine oil and stagger the ring gaps evenly.

Install a new gasket on the supercharger front housing parting surface. Pour clean engine lubricating oil into the crankshaft until it reaches a level covering approximately half of the starter coupling splines.

Thoroughly inspect the diffuser section and inside of the intake pipe bosses to insure no foreign material is present that will cause damage to the engine.

Insert the splined turning tool (Tool No. 82809) into one of the magneto drive shafts and carefully lower the supercharger rear housing into place, turning the gears with the turning tool to engage the splined end of the accessory drive shaft with the crankshaft coupling splines. Exercise care when lowering the housing to prevent damaging the impeller oil seal rings.

If the rear section sticks or any other difficulty is encountered while the supercharger rear housing is being installed, lift it from the engine and inspect the impeller shaft front oil seal rings for possible damage. Insure that rings are not twisted. An oil seal ring that is twisted will prove ineffectual as an oil seal and must be replaced with a new part.

Secure the supercharger rear housing to the front housing with plain washers, nuts, palnuts, and locate the supporting clamp and bracket assembly for the left main ignition manifold on the stud to the left of the impeller oil seal vent.

Remove the supercharger rear housing lifting eye and replace it with a cover plate. Secure the plate with plain washers, nuts, and palnuts.

## IGNITION WIRING MANIFOLD

Place the ignition harness in its approximate position on the engine. Place the two flexible conduits on either side of No. 1 cylinder and place the distributor blocks in their approximate positions at the rear supercharger housing. If the magnetos have been installed, insert the magneto distributor block in its recess in the magneto housing, using extreme care not to damage the contact buttons.

Place the magneto coil cover in its position on the magneto and secure both the magneto distributor block and the coil cover with the six slot-head cap screws using a new lock washer under the head of each cap screw.

Install the four clamps securing the two halves of the ignition harness to the four supports which are bolted to the crankcase front section.

Further assembly of the ignition harness is accomplished after installation of the cylinder air deflectors. After completion of the installation of the cylinder air deflectors, tighten the knurled nuts on each end of the magneto out-

let elbow. Fasten the nuts which secure the braid to the manifold ring and attach these flexible radio shielded ignition leads to the push rod housings by means of the clamps. Secure the ignition leads for the front and rear spark plugs together by means of clamps to prevent vibration of the leads. Place the rear ignition leads in their respective locations in the channel sections of the cylinder head air deflectors.

Hold each terminal securing nut back and apply a thin coat of Dow Corning No. 4 on the surface of each insulating sleeve. Also fill the contact spring secured to each insulating sleeve with the compound. Push the insulating sleeve into the spark plug well until the ridge at the end of the elbow rests in position on top of the spark plug barrel. Since the compound is an insulator, remove any excess which may be forced out at the top of the spark plug barrel with a clean lintless cloth. Secure the terminal elbow to the spark plug. Repeat this procedure for each spark plug terminal.

## OIL SUMP, CYLINDER AIR DEFLECTORS, INTAKE PIPES, ACCESSORIES

**OIL SUMP** Place the sump in its proper position and install the flat washers, nuts, and palnuts insuring that the oil passages are properly lined up. See figure 245.

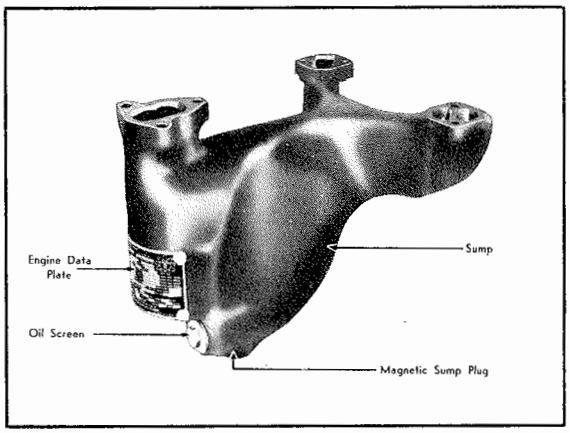



**Fig. 245. Oil Sump**

Check to see that the magnetic sump plug and screened plug are installed and lockwired correctly.

**CYLINDER AIR DEFLECTORS** Place the intercylinder air deflector clamp so that the edges of the channel-shaped clamp fit into the fifth and eleventh fin spaces, counting the space between the first and second fin at the crankcase end of the cylinder as No. 1. Place the air deflector in its approximate position between the cylinders and loosely install the bolt through the deflector, spacer, and clamp. Install a new elastic stop nut but do not tighten it at this time. Line up the deflector so that the stud will protrude through the space between the two rocker box cover extensions. Install the grommet and retaining plate, secure with a new elastic stop nut. Tighten the air deflector clamp at the base of the air deflector.

To install the intercylinder air deflector at the sump location, place the deflector in its approximate position. Loosely install the two cap screws and washers securing the deflector to the two legs of the sump. Line up the stud with the space between the two rocker box cover extensions, install the rubber grommet and retaining plate and secure the assembly with a new elastic stop nut. Tighten the cap screws in the sump legs and lockwire securely.

Place the cylinder-head air deflector in its approximate position and install one of the rocker box cap screws loosely. Install the second cap screw in the opposite rocker box and a third cap screw in the intake pipe mounting flange. Tighten the cap screws and make certain all are lockwired.

**PRIMING SYSTEM** For engines equipped with five point priming, install the priming distributor on the intake pipe to cylinder No. 1 by means of the clamp attached to the distributor. See figure 246. Install the priming lines to the connections on the rocker boxes on cylinders No. 1, 2, 3, 8,

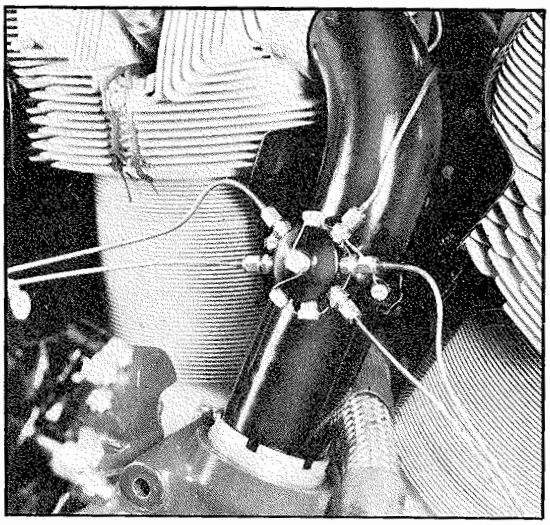


**Fig. 246. Location of Priming Distributor**

and 9. Connect each line to the distributor after it has been installed on the rocker box. Clamp the tubes to the push rod housings.

**INTAKE PIPES** Install a new packing ring in each intake port in the supercharger front housing, and loosely install the nine packing nuts.

Install a new packing ring under the intake pipe attaching flange at the cylinder end. Coat the crankcase end of the intake pipe with clean engine lubricating oil and insert into the supercharger front housing.

Place a new gasket under the intake pipe flange and secure the flange and gasket to the intake port with shake proof washers and three cap screws. Tighten the cap screws evenly and lockwire securely. Tighten the packing nut at the crankcase end of the intake pipe using the crowfoot-type wrench (Tool No. 84258) and handle (Tool No. 81403).

**ADJUSTMENT OF MAGNETO CONTACTS** Before installing the magnetos these instructions should be followed: Be sure the magneto follower is not lodged between the fiber cam follower block and the cam. Should this occur and the points be adjusted, subsequent wear of the felt would change the magneto timing.

Turn the magneto drive shaft in the normal direction of rotation until the timing mark "A" on the distributor rotor lines up with mark "B" on the magneto front end plate. See figures 247 and 248.

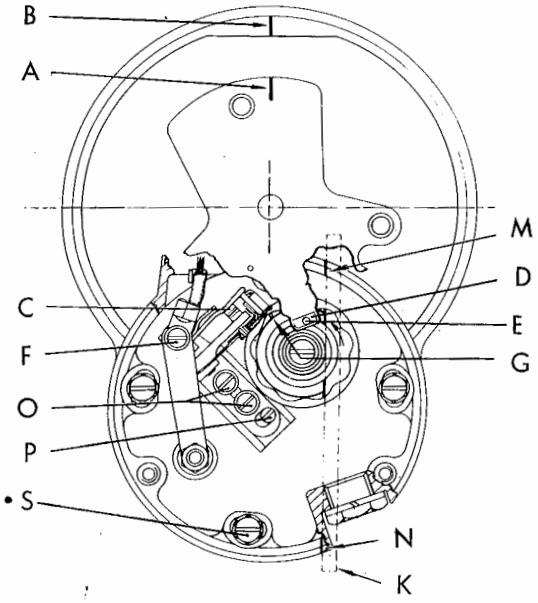



**Fig. 247. Sketch for Magneto Adjustments**

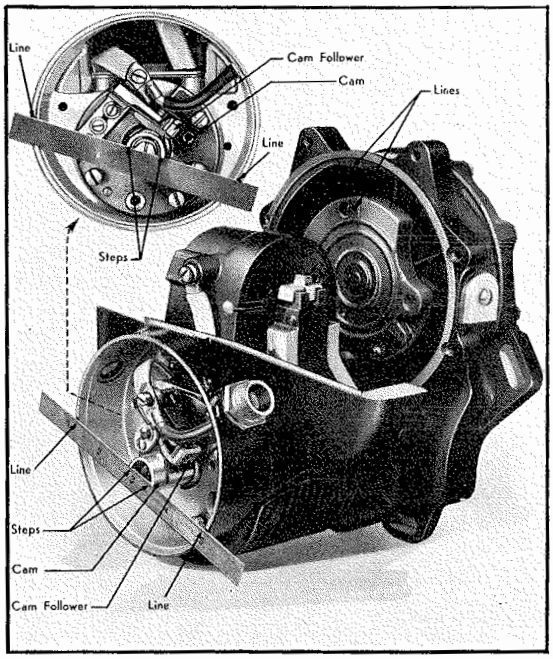



**Fig. 248. Adjusting magneto Timing**

Place a 6 inch (150.4 mm) steel scale "K" against the face of the step cut in the cam "L". Turn the magneto drive shaft slightly until the straight edge coincides with the marks "M" and "N" cut in the rim of the breaker housing. In this position, the high

tension electrode "D" on the distributor finger will be opposite the distributor block electrode "E" for firing the No. 1 cylinder.

These pivotless breakers must always be adjusted so that the contacts open at the proper position of the cam and not for any fixed clearance between the contact points.

If inspection shows that the position of opening of the contacts requires adjustment, loosen the two screws "O", which fasten the breaker support to the breaker housing. Hold the cam in position to open the contacts as indicated by the straight edge and adjust by means of the eccentric screw "P" until the contacts are just opening. Secure them in this position by tightening the screws "O". This adjustment should be necessary only when installing new points or in unusual overhaul cases.

When the exact timing is to be made, all adjustments must be made at the drive end and not by altering the adjustment of the contact points.

**MAGNETO TIMING** Install the timing disk (Tool No. 83517) and adapter (Tool No. 83533 or 800947) on the starter mount pad and rotate the crankshaft in the normal direction of rotation until No. 1 piston is at top center of the compression stroke. Refer to figure 249. Check for top

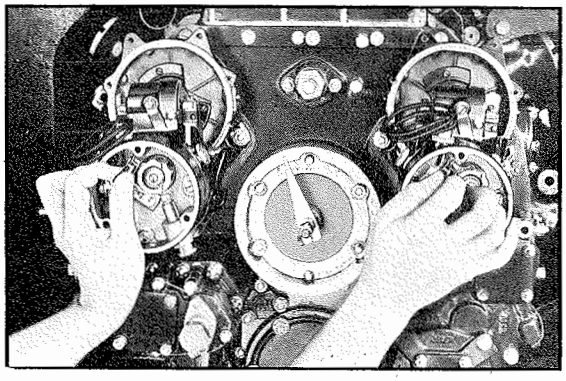


**Fig. 249. Magneto Timing**

center using a top center indicator (Tool No. 80932) in No. 1 cylinder. Adjust the pointer on the timing disk installed on the starter pad to zero when the No. 1 piston is on top center on the compression stroke. Tighten the clamping screw to hold the pointer to its shaft in this position. Turn the crankshaft backward for approximately ¼ of a revolution then forward to the spark timing value indicated on the engine data plate.

The position of opening of the breaker points can be checked by inserting a piece of .001 inch (0.025 mm) feeler stock between the contact points "C" by lifting the felt-covered cam follower "F" which causes the points to open. Do not open the points by lifting the breaker spring "G" as a permanent set may result from bending at the spring pivot.

A better method is to turn the magneto shaft in the direction of rotation until the breaker points are opened by the cam. Insert the feeler gage between the points and turn the magneto shaft in the direction opposite to normal rotation until the points close. Turn the shaft in he direction of normal rotation until the points begin to release the feeler gage indicating that the breaker points are just beginning to open.

Apply a heavy grade of Vaseline to the splines of the magneto coupling gear. With the magneto timing marks aligned as described above, install the magneto on the engine. See figure 250. Move the magneto to its extreme positions allowed by the slots in the mounting flange, noting whether or not the breaker points open and close. If the breaker points open and close approximately

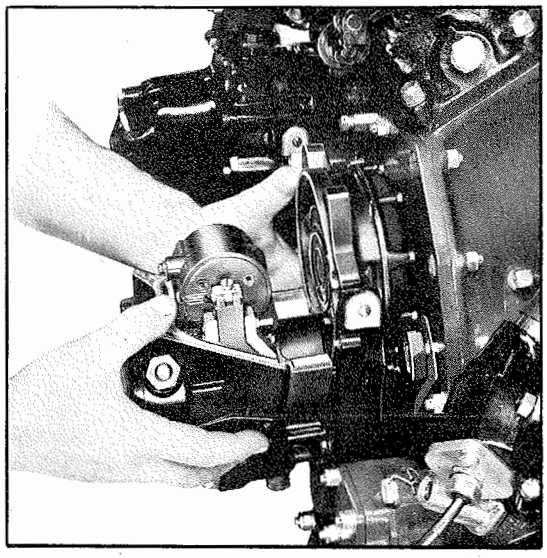


**Fig. 250. Installing Magneto**

half way between the two stops, assemble the flat washers and nuts on the magneto studs. Tighten the nuts sufficiently to hold the magneto firmly on the cover but not tight enough to prevent adjusting the position of the magneto. If the breaker points open at the middle of the travel of the magneto, further adjustment of the spark, either advance or retard, can be obtained to a certain degree without removing the magneto from the engine.

If the breaker points do not open while turning the magneto, remove the magneto from the engine and turn its shaft until the timing marks are lined up as described above and as shown in figures 247 and 248. Fit the magneto again to the engine and test to see if the breaker points open. Continue this until proper opening is obtained.

Another method for resetting a magneto whose breaker points do not open during the angle allowed by the slots in the flange is as follows: Withdraw the magneto from the engine, install the magneto coupling wrench (Tool No. 82676) over the splined drive shaft coupling to keep the shaft stationary, and remove the cotter pin, castellated nut, and washer which retain the coupling on the shaft. The coupling which is fitted to the shaft by six slots on its inside diameter, should be withdrawn, turned to the next slot engaging position, and reinstalled on the shaft. Install the retaining washer and nut and check the opening and closing of breaker points with the magneto on the engine. When the results are satisfactory, withdraw the magneto to install the cotter pin in the coupling retaining nut, and reinstall the magneto on the engine.

As the contacts begin to open, place the straight edge "K" on the timing marks "M" and "N" on the breaker adapter and check that they line up with the step on the cam. It may be found that timing mark "A" on the distributor finger is not exactly opposite the timing mark "B" on the inside of the front end plate after making the final adjustment by having the straight edge "K" on the cam coinciding with the timing marks "M" and "N". However, any slight variance of the distributor finger timing mark "A" will not affect the operation of the magneto as this is merely used to locate the approximate firing position of the magneto for No. 1 cylinder.

The timing hole on the left side of the crankcase front section can be used to check for top center of No. 1 piston for magneto timing. Looking through the timing inspection hole, a crank angle degree scale ranging from 0 deg. to 35 deg. before top center of No. 1 piston is seen etched on the rim of the reduction driving gear. When No. 1 piston is on top center on the compression stroke, the line on the rear of the timing inspection hole will line up with the 0 deg. mark on the reduction driving gear scale. When the breaker points open, the reading on this scale should correlate with that reading specified on the engine data plate for magneto advance.

If the .001 feeler has not been installed, install it at this time by moving the magneto as described above. Tighten the three flange attaching nuts to secure the magneto at this location.

Check the setting by turning the propeller shaft backward about a quarter of a revolution. Tap the propeller shaft slowly in the normal direction of rotation stopping when the breaker points commence to open, or when the feeler is released from the breaker points. Observe the angle reading on the timing disk mounted on the starter or on the reduction driving gear scale and check that it agrees with that reading on the engine data plate.

If the opening of the magneto points does not coincide with the figures noted on the engine data plate, loosen the magneto attaching nuts, turn the crankshaft to the proper timing setting as indicated on the timing disk, readjust the magneto so that the feeler is just ready to loosen and recheck the timing.

When the correct timing has been established, check the attaching nuts for tightness and secure them with cotter pins.

If the magneto timing is staggered, it is advisable to install the magneto having the greatest amount of advance first. However, if both magnetos have the same amount of advance, both may be installed, timed, and checked at the same time. See figure 249.

The magnetos may also be timed and checked by using the timing light (Scintilla Tool No. 4-19658). This timer works on 110

volts 60 cycle A. C. systems and is designed to check the contact point opening without inserting insulating material between the points or breaking the primary circuit of the magneto.

To check the contact point setting, connect the red leads to the insulated contact points of each magneto and then connect the black lead to ground. Do not place insulating material between the contact points as the primary circuit does not have to be broken.

When the contact points are closed, the flash light bulb covered by a colored glass will give a comparatively bright light as the current is not absorbed by the primary winding of the coil. When the points are opened the light will be dimmed considerably and made practically invisible by the colored glass.

Proceed as above for checking magneto timing. For magnetos that are synchronized, both lights should go out at the same time and at a position agreeing with that on the engine data plate. For staggered spark advance, the magneto with the greater amount of advance will have its breaker points open first and can be checked before continuing to check the remaining magneto.

When both magnetos have been timed satisfactorily, install the plug in the timing inspection hole in the crankcase front section with the copper-asbestos gasket under its head. Tighten and lockwire this plug.

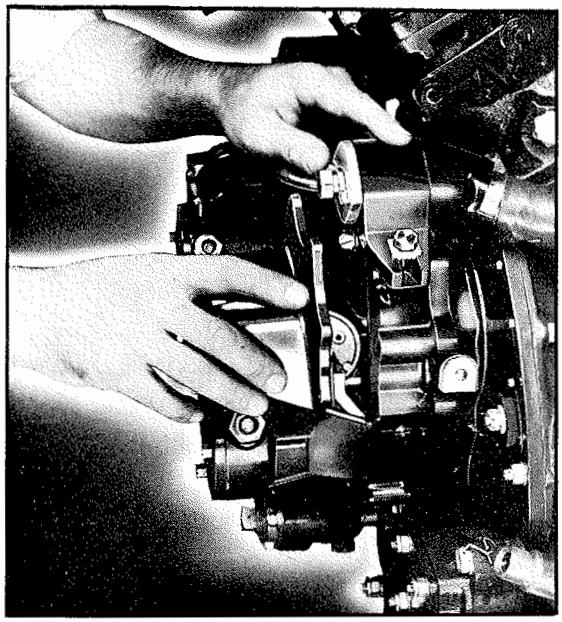


**Fig. 251. Installing Magneto Coil Cover**

Install the breaker housing cover and tighten the two hex-head cap screws which are retained in the cover by circlets. See figure 251. Check the cap screws for a lock washer under the head of each.

Reinstall the distributor block, coil cover, radio shielding and ground terminals as described under IGNITION WIRING MANIFOLD in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES.

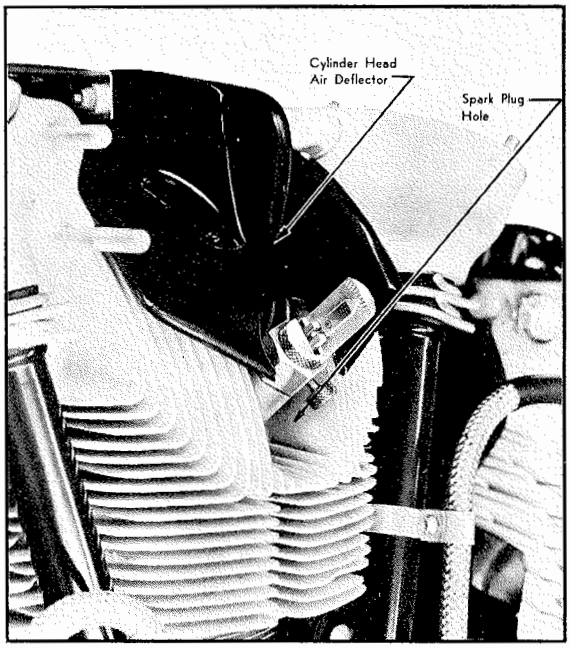



**Fig. 252. Top Center Indicator**

**CHECKING VALVE TIMING** Check the valve timing by installing a top center indicator in the front spark plug hole of No. 1 cylinder. See figure 252. Mount timing disk (Tool No. 83517) with adapter (Tool No. 800947) on engines equipped with detachable starter dog of 12 teeth and the same timing disk with adapter (Tool No. 83533) on engines equipped with detachable three-jaw starter dog on the starter mounting pad and secure it with regular starter attaching nuts.

Install engine turning hub (Tool No. 82889) on the propeller shaft and note the top center indicator pointer when the crankshaft is turned to determine if the pointer arm is contacting the piston properly. This may be de-

termined by slowly turning the crankshaft until the piston nears the top center position and contacts the pointer arm. If the pointer arm is properly adjusted, the pointer will rise a few graduations as the piston approaches its top center position, pause for a moment and then return to its original position as the piston moves on its downward stroke. If the pointer moves upward off the graduated scale as the piston approaches top center, reverse the crankshaft rotation, remove the top center indicator and readjust the angle of the pointer arm in an upward direction. If the arm does not move, adjust it in a downward position. Repeat this procedure until the top center indicator is adjusted to register properly.

Adjust the pointer on the timing disk to read zero when the top center indicator shows the piston in No. 1 cylinder to be on the top center of its compression stroke. This may be checked as follows: Turn the crankshaft in the direction of rotation until the pointer on the top center indicator is in the middle of the graduated scale. Note the reading in degrees indicated by the pointer on the timing disk.

Continue to turn the crankshaft until the pointer on the top center indicator has completed its upward stroke and has returned to the point at which the first reading was taken. Again note the reading in degrees indicated by the timing disk pointer. The exact top center position is the point midway between the two timing disk readings.

Turn the crankshaft in the opposite direction of rotation for approximately one-quarter turn, then turn it in the direction of rotation to the point midway between the two readings previously obtained and adjust the zero mark on the timing disk to coincide with the pointer.

Adjust the clearance of both valves to the timing value specified on the engine data plate.

Turn the crankshaft in the direction of rotation until the piston in No. 1 cylinder is 30 to 35 degrees before top center on the exhaust stroke.

From this point move the crankshaft forward slowly by tapping the turning hub handle until the No. 1 intake rocker roller just contacts the valve stem tip, indicating that the valve is starting to open. As soon as the roller tightens against the valve tip, note the reading on the timing disk. Continue to turn the shaft forward until the No. 1 exhaust rocker arm roller is free, indicating that the exhaust valve has closed and note the reading on the timing disk. If the cam gears have been meshed properly, the valve clearance adjusted accurately and the check carefully made, the readings obtained should check within a few degrees of the valve timing specifications given on the engine data plate. An error of one tooth made in the meshing of the cam gears will cause the readings obtained to vary considerably from the specified timing.

After completing the valve timing check, reset the valves in No. 1 cylinder, following the instructions given regarding the location of the oil holes in the adjusting screws. Pour ½ pint of engine lubricating oil into the rocker boxes and install the rocker box gaskets and covers.

Remove the timing disk from the starter mounting pad and reinstall the gasket and cover plate.

Remove the top center indicator and reinstall the dummy spark plug. Install the plug in the front section inspection hole and secure with stainless steel lock wire.

**SPARK PLUGS** Spark plugs which have been sprayed with preservative compound should be thoroughly cleaned, dried out and bomb tested before installing them in the engine. Plugs should be washed with a good grade of gasoline to which no detonation inhibitor or coloring matter has been added. After washing, the plugs should be allowed to dry in the open air. Compressed air should not be used to clean or dry spark plugs.

The gaps should then be checked and if found greater than .012 inch (0.304 mm) they should be adjusted to this figure.

Check the thickness of the solid type copper spark plug washer and the spark plug type thermocouples. Do not use either type if it does not conform with the following dimension: Minimum thickness of 0.068 inch (1.73 mm), maximum thickness 0.095 inch (2.41 mm).

Remove the dummy spark plugs.

Install solid copper washers on all the spark

plugs on the cylinder head threads except for those plugs on which a thermocouple type washer is used.

Install and tighten the spark plugs to the proper torque value using wrench (Tool No. 84458) for plugs having a ⅞ inch (22.22 mm) hex nut and wrench (Tool No. 84457) for plugs with a one inch (25.4 mm) hex nut. (Refer to the applicable Table of Limits.) See figure 253.

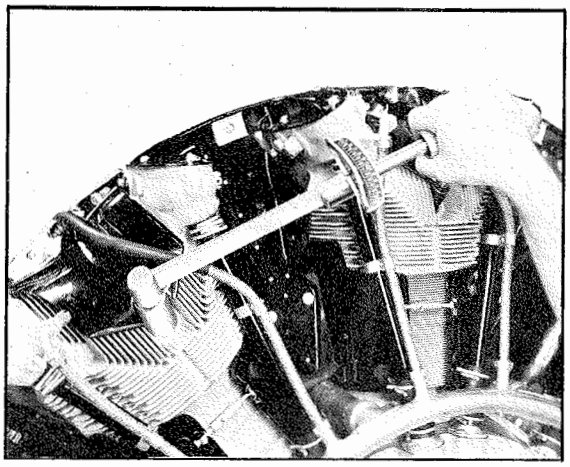


**Fig. 253. Installing Spark Plug Using Torque Wrench**

Install a small spark plug shielded terminal elbow copper washer over the contact of each spark plug, clean the contact sleeves with a cloth saturated with carbon tetrachloride. Do not touch them with the fingers since the salt from any perspiration which might be on the hands will produce arcing and corrosion. Attach the elbows to the plugs.

**INSTALLING BENDIX STROMBERG CARBURETOR** To install the carburetor, turn the engine to the front-end-up position. With the engine in a horizontal position, any foreign particle might easily fall into the induction passage and cause considerable damage to the impeller should the crankshaft be turned.

Remove the plate covering the induction passage opening and install a new carburetor adapter gasket.

Install the carburetor, along with the adapter attached as a unit to the carburetor, and secure with spherical seat washers, nuts, and palnuts.

Install a gasket on each side of the air screen and lock in place on two diagonally opposite studs. Cover the carburetor immediately with oil cloth or some similar material and secure to carburetor with an elastic or bailing wire. This will prevent foreign matter passing the screen into the supercharger section. Keep the carburetor covered until ready to install the carburetor air scoop.

**INSTALLING HOLLEY OR CHANDLER EVANS CARBURETOR** With the engine front-end up, remove the plate covering the induction passage opening, install a gasket over the engine attaching studs, install the carburetor adapter and secure with the spherical seat washers and nuts on the six external attaching studs. Lock the nuts with palnuts. Install spherical seat washers and castellated nuts on the two attaching studs inside the adapter. Tighten the nuts and secure them with lock wire.

Place a new gasket over the carburetor lower attaching studs, install the carburetor on the adapter and secure it with spherical washers, nuts, and palnuts.

Place a gasket over the vent ring attaching studs, being sure that the holes in the gasket index with the holes in the carburetor mounting flange. Install the vent ring again, insuring that the holes are in proper alignment.

Place a new gasket on each side of the carburetor air screen and install over the air scoop attaching studs on the vent ring and hold them in place until ready to install the air scoop with plain washers and nuts. Cover the carburetor with oil cloth as for Bendix Stromberg carburetors.

After the air scoop has been installed, secure the attaching nuts with palnuts.

**THRUST BEARING NUT** Tighten the thrust bearing nut using wrench (Tool No. 82889) and a suitable hammer. Check the distance between the end of the propeller shaft and the front face of the thrust nut. Refer to the Installation Drawing in the Appendix of this book. This measurement should agree with the drawing within plus or minus 1/64 inch (0.39 mm).

If, due to the replacement of parts, the

measurement is found to be under the low limit, it is permissible to remove the thrust nut and reduce its thickness by grinding the front face, provided not more than .005 inch (0.13 mm) is removed from a new nut. Once the front face of a thrust nut has been ground, the nut should be identified to prevent subsequent grinding at the next overhaul. Due to the shallow depth of the case hardening of this nut, it is important that the amount of material ground off the front face be limited as specified.

If the measurement is over the high limit, it will be necessary to install a new thrust nut.

A new or reworked thrust nut and ring assembly should be installed in accordance with the instructions given under PROPELLER SHAFT AND PINIONS—.666 (3:2) REDUCTION GEAR in the chapter entitled REPAIR AND ASSEMBLY OF SUBASSEMBLIES.

## CHAPTER VII

# TESTING ENGINES AFTER OVERHAUL

**GENERAL** After the engine has been overhauled, it should be thoroughly tested. This test should be more than a run-in of the new parts installed. It serves as a check on fuel consumption, oil consumption, oil flow, cylinder-head temperatures, and power output of the engine.

Two methods of engine testing are normally employed. The differences in these two methods are in the manner in which the power of the engine is absorbed. The simplest and most economical type of test may be run with a four-blade wooden test club to absorb the load. The second method employs an electric cradle-type dynamometer or water brake to absorb the load. This latter type of test requires more expensive equipment, experienced operators, and frequent calibration of the apparatus to check engine performance accurately. For these reasons, it is recommended that the rigid type test stand employing a propeller as a medium of absorbing power be used.

Regardless of the type of stand used, propeller or dynamometer, the same readings, as far as engine operation is concerned, should be taken. It is recommended that the test stand equipment include positive methods of controlling engine oil temperature, carburetor air temperature, and fuel temperature. Accurate scales should be available for checking fuel and oil consumption. The log sheet should be kept and the following readings be recorded on it during the last five minutes of each period except as noted and except where periods are of longer duration than 20 minutes, in which case readings should be recorded every 15 minutes.

(1) Time of day
(2) Throttle position
(3) Manifold pressure
(4) RPM
(5) Pounds of oil on scale
(6) Oil pressure
(7) Oil in temperature
(8) Oil out temperature
(9) Oil flow (one reading at 85% and one reading at 100% rated manifold pressure)
(10) Time for consumption of stated weight of fuel
(11) Carburetor air scoop temperature
(12) Fuel pressure
(13) Cylinder-head temperatures, No. 1, 4, and 7
(14) True barometer
(15) Dry air barometer pressure (one reading at start and every three hours during test)
(16) Dry bulb temperature
(17) Wet bulb temperature

See figure 254.

WRIGHT AERONAUTICAL CC
(A DIVISION OF CURTISS-WI

CONTRACT NO. W535 AC 24543 ROUTINE ENGINE INSPECTION TEST LOG

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W.A.C. MODEL GR1820-G666 | | | W.A.C. TEST SPEC. 1027 | | | | W.A.C. FUEL SPEC. 5804 & 5806 | | | TEST STAND NO. P-12 | | | CARB. MFR. STROMBERG | | | MAG. MFR. AMER. BOSCH | | | STARTER | | | | | | | | | | | | |
| W.A.C. NO. 82213 | | | CUST. TEST SPEC. AN 9503 | | | | CUST. FUEL SPEC. 90 + 100 | | | TEST STAND TYPE CABLE | | | CARB. MODEL PD 12H2 | | | MAG. MODEL SF9LU-3 | | | GENERAT | | | | | | | | | | | | |
| CUST. MODEL | | | COMP. RATIO 6.70 : 1 | | | | OCT. NO. | | | DYN. CONSTANT | | | CARB. SER. NO. 241082A | | | R.H. MAG. NO. 11692 | | | CONTROL | | | | | | | | | | | | |
| CUST. NO. AF 42-138492 | | | BLOWER RATIOS 7.0 : 1 | | | | W.A.C. OIL SPEC. 5815-C | | | COUNTER WEIGHT STA. ✓ | | | PRESS. REQD. 14-16 PSI | | | L.H. MAG. NO. 12039 | | | FUEL PU | | | | | | | | | | | | |
| RATED H.P. AT S.L. 1000 | | | RED. GEAR RATIO 16 : 9 | | | | CUST. OIL SPEC. AN-VV-O-446 | | | TEST CLUB NO. 18659 | | | GRAVITY FEED PUMP | | | ADVANCE L.H. 20 °B.H. 20 ° | | | VACUUM | | | | | | | | | | | | |
| RATED R.P.M. 2300 | | | TACH. DR. RATIO ½ : 1 | | | | VISCOSITY S.A.E. 120 | | | TEST CLUB DIA. 91" | | | | | | SPARK PLUGS ACLS-87 | | | | | | | | | | | | | | | |

| | A.M. OR P.M. | START OR STOP | TIME OF DAY | % RATED SPEED | MIX. CONT. POS. | MAN. PRESS. IN. HG. | ABS. MAN. PRESS. IN. HG. | R.P.M. BY COUNTER | DYN. LOAD RAD. | TORQUE METER #/D" | TORQUE METER CONST. | OBS. H.P. | CORR. H.P. | LBS. FUEL PER OBS. H.P. HR. | LBS. OIL PER OBS. H.P. HR. | LBS. OIL PER HOUR | LBS. OIL ON SCALES | ENGINE OIL PRESS. #/D" | HYDRO OIL PRESS. #/D" | VACUUM OIL IN | CLUTCH PRESS. LOW #/D" | CLUTCH PRESS. HIGH #/D" | OIL TEMPERATURE IN °F. | OIL TEMPERATURE OUT °F. | OIL TEMPERATURE RISE °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P.M. | START | 4:30 | P.T. | F.R | | | 900 | | | - OIL | PREHEATED - | | | | | 90.0 | 78 | 60 | | | | 165 | | |
| | | | 4:40 | 58 | A.R | -10.0 | 19.56 | 1340 | | | | | | | | | 75.8 | 65 | 55 | | | | 188 | 200 | 12 |
| | | | 4:50 | 67 | AR | -8.0 | 21.56 | 1540 | | | | | | | | | 104.0 | 67 | 55 | | | | 188 | 210 | 22 |
| | | | 4:55 | 74 | AR | -4.2 | 25.36 | 1720 | | | | | | | | | 101.0 | 67 | 53 | | | | 185 | 210 | 25 |
| | | | 5:00 | 74 | AL | -4.2 | 25.36 | 1720 | | | | | | | | | 100.7 | 67 | 53 | | | | 184 | 211 | 27 |
| | | | 5:00 | 84 | AR | +0.3 | 29.86 | 1940 | | | | | | | | | | | | | | | | | |
| | | | 5:15 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .509 | | | 100.2 | 66 | 49 | | | | 185 | 225 | 40 |
| | | | 5:30 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .509 | | | 100.0 | 66 | 49 | | | | 185 | 224 | 39 |
| | | | 5:45 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .509 | | | 98.7 | 66 | 50 | | | | 185 | 229 | 44 |
| | | | 6:00 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .512 | | | 97.6 | 66 | 50 | | | | 185 | 230 | 45 |
| | | | 6:15 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .512 | | | 96.2 | 66 | 50 | | | | 185 | 230 | 45 |
| | | | 6:30 | 84 | AR | +0.3 | 29.86 | 1940 | | | | 609 | 620 | .512 | | | 96.0 | 66 | 50 | | | | 185 | 230 | 45 |
| | | | 6:35 | 95 | AR | +6.5 | 35.94 | 2200 | | | | 847 | 862 | .610 | | | 96.8 | 65 | 46 | | | | 185 | 235 | 50 |
| | | | 6:40 | 100 | AR | +10.5 | 39.94 | 2300 | | | | 994 | 1014 | .643 | | | 97.0 | 66 | 45 | | | | 185 | 241 | 56 |
| | | | 6:40 | 95 | AR | +6.5 | 35.94 | 2200 | | | | | | | | | | | | | | | | | |
| | | | 6:45 | 95 | AR | +6.5 | 35.94 | 2200 | | | | 847 | 862 | .610 | | | 96.8 | 66 | 46 | | | | 185 | 237 | 52 |
| A- | | | 6:55 | 95 | AR | +6.5 | 35.94 | 2190 | | | | 843 | 860 | .603 | | | 96.4 | 65 | 47 | | | | 184 | 237 | 53 |
| | | | 7:05 | 95 | AR | +6.5 | 35.94 | 2190 | | | | 843 | 860 | .600 | .00355 | 3.0 | 95.8 | 65 | 47 | | | | 184 | 237 | 53 |
| | | | 7:10 | 95 | AR | +6.5 | 35.94 | 2190 | | | | 843 | 860 | .600 | | | | 65 | 47 | | | | 184 | 237 | 53 |
| | | | 7:10 | 100 | AR | +10.6 | 40.01 | 2300 | | | | | | | | | | | | | | | | | |
| | | | 7:15 | 100 | AR | +10.6 | 40.01 | 2300 | | | | 998 | 1017 | .639 | | | 95.2 | 66 | 45 | | | | 182 | 240 | 58 |
| | | | 7:25 | 100 | AR | +10.6 | 40.01 | 2290 | | | | 995 | 1015 | .638 | | | 94.9 | 67 | 46 | | | | 182 | 242 | 60 |
| | | | 7:35 | 100 | AR | +10.6 | 40.01 | 2300 | | | | 998 | 1017 | .639 | .00182 | 1.8 | 94.6 | 67 | 46 | | | | 182 | 242 | 60 |
| | | | 7:40 | 100 | AR | +10.6 | 40.01 | 2300 | | | | 998 | 1017 | .631 | | | | 67 | 46 | | | | 182 | 242 | 60 |
| | | | 7:41 | P.T. | AR | -12.0 | 17.41 | 1050 | | | IDLE ENGINE BEFORE T.O. | | | | | | | | | | | | | | |
| | | | 7:46 | T.O. | F.R. | +17.4 | 46.81 | 2450 | | | | 1201 | 1223 | .700 | | | 93.4 | 66 | 44 | | | | 188 | 244 | 56 |
| B- | P.M. | STOP | 7:51 | FOR INSPECTION | | | | | | | | | | | | | | | | | | | | | |
| | P.M. | START | 8:10 | P.T. | FR | - | - | 1200 | | | - OIL | PREHEATED - | | | | | 80.0 | 70 | 60 | | | | 166 | | |
| | | | 8:15 | CLEAR LINES OF LEADED FUEL | | | | | | | | | | | | | | | | | | | | | |
| | | | 8:30 | P.T. | FR | -12.0 | 17.41 | 1050 | | | - 65 OCTANE FUEL - | | | | | | 76.0 | 67 | 57 | | | | 188 | 200 | 12 |
| | | | 8:45 | P.T. | FR | -12.0 | 17.41 | 1050 | | | - 65 OCTANE FUEL - | | | | | | 75.2 | 61 | 57 | | | | 188 | 200 | 12 |
| | | STOP | 8:46 | | | | | | | | | | | | | | | | | | | | | | |

NOTES: FUEL, OIL AND WATER LEAKS, ETC.

A - CHANGE FROM 90 OCTANE TO 100 OCTANE FUEL.

B - DRAIN OIL SUPPLY TANK + REFILL WITH CLEAN OIL - SUMP DRAINED.

CARB. ACCEPTED ON AIR BOX TEST.

| CARBURETOR PERFORMANCE | | | |
|---|---|---|---|
| ACCEL. SLOW | OK | RAPID | OK |
| IDLING | 525 RPM | FLOOD | NO |
| OPER. BELOW 1000 R.P.M. | | | OK |
| FUEL CUT OFF SECS. | | | 2.5 @ 700 RPM |
| IDLING OIL PRESS. | | | 32 PSI @ 189°F. |

| MAGNETO PERFORMANCE | | |
|---|---|---|
| BOTH MAGS. | 1960 RPM | STARTE |
| R.H. ONLY | 1910 " | GENERA |
| L.H. ONLY | 1930 " | GEN. CO |
| SHUT OFF | OK | FUEL PU |
| SPARK PLUGS | OK | VACUUM |

Fig. 254.

**CAL CORPORATION,** PATERSON, N. J.

(CURTISS-WRIGHT CORPORATION)

SHEET NO. ONE DATE JUNE 12, 1943

| ACCESSORIES | TYPE | SER. NO. |
|---|---|---|
| STARTER BENDIX | TEST | WAC #60 |
| GENERATOR | | |
| CONTROL | | |
| FUEL PUMP PESCO | TEST | WAC #52 |
| VACUUM PUMP | | |

ENGINE TIMING: CYL. NO. ONE; INL. OPEN 14° BTC CLOSE; EXH. OPEN CLOSE 20° ATC; CLEARANCE .0075" COLD; M. ROD CYLS. ONE

| WEATHER TIME | | | |
|---|---|---|---|
| | 4:30 | 6:35 | 7:10 |
| OBS. TRUE BAROM. | 30.02 | 30.03 | 29.99 |
| DRY BULB °F | 82 | 80 | 78 |
| WET BULB °F | 66 | 69 | 68 |
| VAPOR PRESS. | .46 | .59 | .58 |
| DRY AIR PRESS. | 29.56 | 29.44 | 29.41 |

| TEMPERATURE OUT °F | TEMPERATURE RISE °F | OIL FLOW LBS./MIN. | HEAT REJECT TO OIL B.T.U. | CORR. HEAT REJ. | FUEL PRESS. #/□" | FUEL TEMP. °F. | ROTO M.M. | FUEL TEMP ~~ROTO~~ NO °F. | CARBURETOR AIR: LBS. FUEL PER HOUR | TEMP. °F. | PRESS. IN. $H_2O$ | PRESS. IN. HG. | W.O.T. H.P. CORR. FACTOR | COOLING AIR PRESS. $H_2O$ | COOLING AIR TEMP. °F. | RED. GEAR TEMP. °F. | CYL. HEAD TEMP. # / °F. | CYL. HEAD TEMP. # °F. | REAR SECTION PRESS. IN. $H_2O$ | PURO. BACK PRESS. P.S.I. | CORRECTED OIL FLOW #/MIN. | CORRECTED OIL RISE °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | 12 | | | | 15.5 | 70 | 4.0 | 70 | 115 | 76 | 0.0 | | | | 80 | | 240 | | -0.3 | 7.0 | | |
| 210 | 22 | | | | 15.6 | 71 | 6.0 | 70 | 155 | 78 | 0.0 | | | | 81 | | 320 | | -0.3 | 7.0 | | |
| 210 | 25 | | | | 15.7 | 71 | 9.0 | 70 | 217 | 78 | 0.0 | | | | 81 | | 315 | | -0.4 | 7.5 | | |
| 211 | 27 | | | | 15.7 | 71 | 7.9 | 70 | 195 | 79 | 0.0 | | | | 81 | | 330 | | -0.4 | 8.0 | | |
| 225 | 40 | | | | 15.7 | 71 | 13.6 | 70 | 310 | 80 | 0.0 | | | | 82 | | 360 | | -0.5 | 9.0 | | |
| 224 | 39 | | | | 15.7 | 71 | 13.6 | 70 | 310 | 80 | 0.0 | | | | 81 | | 360 | | -0.5 | 9.0 | | |
| 229 | 44 | | | | 15.7 | 71 | 13.6 | 70 | 310 | 80 | 0.0 | | | | 81 | | 365 | | -0.5 | 9.0 | | |
| 230 | 45 | | | | 15.7 | 71 | 13.7 | 70 | 312 | 80 | 0.0 | | | | 81 | | 365 | | -0.5 | 9.0 | | |
| 230 | 45 | | | | 15.7 | 71 | 13.7 | 70 | 312 | 80 | 0.0 | | | | 81 | | 365 | | -0.5 | 9.0 | | |
| 230 | 45 | | | | 15.7 | 71 | 13.7 | 70 | 312 | 80 | 0.0 | | | | 81 | | 365 | | -0.5 | 9.0 | | |
| 235 | 50 | | | | 15.6 | 71 | 23.0 | 70 | 517 | 80 | 0.0 | | | | 79 | | 370 | | -0.4 | 9.5 | | |
| 241 | 56 | | | | 15.5 | 71 | 28.2 | 70 | 640 | 80 | 0.0 | | | | 80 | | 375 | | -0.7 | 10.0 | | |
| 237 | 52 | | | | 15.6 | 71 | 23.0 | 70 | 517 | 80 | 0.0 | | | | 79 | | 370 | | -0.4 | 9.5 | | |
| 237 | 53 | | | | 15.6 | 70 | 22.8 | 70 | 510 | 80 | 0.0 | | | | 79 | | 365 | | -0.4 | 9.5 | | |
| 237 | 53 | | | | 15.6 | 70 | 22.7 | 70 | 507 | 80 | 0.0 | | | | 79 | | 365 | | -0.4 | 9.5 | | |
| 237 | 53 | | | | 15.6 | 70 | 22.7 | 70 | 507 | 80 | 0.0 | | | | 79 | | 365 | | -0.4 | 9.5 | | |
| 240 | 58 | | | | 15.5 | 70 | 28.0 | 70 | 635 | 80 | 0.0 | | | | 78 | | 365 | | -1.0 | 10.0 | | |
| 242 | 60 | | | | 15.5 | 70 | 27.9 | 70 | 633 | 80 | 0.0 | | | | 78 | | 370 | | -1.0 | 10.0 | | |
| 242 | 60 | 60 | 1800 | 1643 | 15.5 | 70 | 28.0 | 70 | 635 | 80 | 0.0 | | | | 77 | | 370 | | -1.0 | 10.0 | 62.0 | 53.0 |
| 242 | 60 | 60 | 1800 | 1643 | 15.5 | 70 | 27.9 | 70 | 633 | 80 | 0.0 | | | | 77 | | 370 | | -1.0 | 10.0 | 62.0 | 53.0 |
| 244 | 56 | | | | 15.4 | 70 | 36.4 | 70 | 840 | 80 | 0.0 | | | | 77 | | 380 | | -0.8 | 11.0 | | |
| 200 | 12 | | | | 15.3 | 70 | — | 70 | — | 75 | 0.0 | | | | 74 | | 270 | | -0.1 | 6.0 | | |
| 200 | 12 | | | | 15.3 | 70 | — | 70 | — | 75 | 0.0 | | | | 74 | | 270 | | -0.1 | 6.0 | | |

| ANCE RPM | ACCESSORY PERFORMANCE | TEST EQUIPMENT |
|---|---|---|
| " | STARTER | OK |
| " | GENERATOR | |
| | GEN. CONTROL | |
| | FUEL PUMP | OK |
| | VACUUM PUMP | |

TESTER J. DOE
OBSERVER S. ROE

RATED J. SMITH
TAKE OFF J. SMITH
FINAL ACCEPTANCE J. SMITH
PRODUCTION TEST

TYPE OF TEST FINAL

Test Log Sheet

**TEST PROPELLER** When a Cyclone engine is to be tested, it should be fitted with a test propeller. Information concerning procurements of test propellers and hub assemblies may be secured upon request to the engine manufacturer. Steel hubs are fitted into the hubs of wooden propellers, and the blades are cut only to the approximate dimensions, which will permit the engines to develop their sea level revolutions per minute without exceeding the maximum permissible sea level manifold pressure. The blade should be trimmed to the proper length to obtain the above conditions during the final calibration in the actual locality and on the actual test stand with which they are to be used. It is of the utmost importance that this calibration and trimming be done accurately.

(1) To determine how much reduction in diameter is required, it will be necessary to install the propeller as received on the engine and make a check run. Atmospheric conditions at the time of the check run should be noted so that subsequent trials after trimming can be made under atmospheric conditions which closely check with the original conditions. A one inch reduction in diameter of the C9GC test propeller will result in increased speed of approximately 50 rpm for the same manifold pressure, where the atmospheric conditions check as mentioned above.

(2) The main object is to determine if rated speed can be obtained without exceeding the rated manifold pressure plus a tolerance of 2%. Refer to (4) below.

(3) For a given manifold pressure, the engine speed can vary plus or minus 2% of its rated speed. Refer to (4) below.

(4) If trimming of the test propeller is accomplished during warm weather conditions, trim for maximum tolerance on rated speed and minimum tolerance on rated manifold pressure. If trimming of the test propeller is accomplished during cold weather conditions, trim for minimum tolerance on rated speed and maximum tolerance on rated manifold pressure.

(5) If the instructions in (4) above are followed, it will permit the use of the same test propeller for a wider range of climatic conditions for a given location plus variables in wind direction at test cell location.

(6) The engine used for the initial and subsequent trials during the trimming and balancing process should be a new engine or one known to have normal power output within normal tolerance for speed and manifold pressure.

The following equipment and instructions may be used for the purpose of trimming and balancing wood test propellers.

(1) A balancing stand complete with arbors, centering cones, and lock nuts should be procured. Install the balancing stand level in a location free from vibration and draft. A man well trained in the use of wood-working tools should do the trimming, balancing, and finishing of the propeller blades when calibrating test propellers.

The procedure for the trimming is given herewith and is itemized for reference convenience.

(1) With the propeller resting flat on a steady rest, draw a line through the center of the blade width on the front surface of each blade. A tool or hard pencil must not be used for marking this line, as to do so would result in cutting into the fabric covering secured to the blade.

(2) Measure off on each blade tip ½ the desired propeller diameter reduction, and through each point scribe an arc whose radius is ½ the width or chord of each blade. For example, if it is desired to reduce the overall diameter 1 inch, the ½ inch should be measured from the blade tip of each blade through which point the arc scribed will pass resulting in rounding the tip of the blade exactly half a circle.

(3) Trim each blade with a saw keeping the cut parallel to the scribed arc and square with the surface of the blade. Where the cut passes through metal armor, the correct saw must be used, and in the event the armor retaining screw is in line with the cut, the solder filler on the head of the screw must be removed and the screw backed out and entirely removed. No attempt should be made to cut through any armor retaining screws, as to do so may permit the remaining section of the screw to be thrown from the blade under centrifugal force.

(4) Upon completion of the cutting, the

centering cone seat in the steel hub should be thoroughly cleaned. Lock the centering cone with the arbor securely in position and mount the propeller and arbor assembly on the balancing stand.

(5) With the propeller assembly resting on the straight edges, slowly rotate the propeller several times to insure that there is no friction offered to the free movement of arbor in order that perfect static balance may be accomplished.

(6) Place any pair of blades in a horizontal position and note which is the heavier, then using a draw knife or wheel spoke shaper, begin the process of trimming, keeping the radius of the blade in its true form and blending the edges of the cut in a round form. It is important that the end of the blade be of round section and not chamfered for the reason that, when in operation, if the end is chamfered, the air will attack the chamfered edges causing rapid erosion and splintering, which will affect the balance and weight of the propeller. A suitable file should be used for trimming where the radius passes through the metal armor.

(7) Upon completion of the trimming of the two blades which should be accomplished alternating from one blade to the other so that static balance and trimming to the required shape will be obtained, place the opposite pair of blades in a horizontal position and repeat the process described in Item (6).

(8) When all four blades have been trimmed and are statically balanced horizontally as described in Items (6) and (7), revolve the propeller several times slowly and then set in position so that the blades are 45 deg. off the vertical, and proceed again as in Items (6) and (7) if the propeller does not remain in true static balance.

(9) Check the opposite pair of blades in the same manner as described in Item (8) and retrim if necessary to obtain the true static balance.

(10) The propeller should be moved through an arc of 45 deg. and back to station at which you are processing as in Items (5) to (10) for each fractional amount of material being removed from each tip.

(11) Upon completion of Items (5) to (10), slowly revolve the propeller and let it come to rest without assistance. If in true static balance, the mass of any pair of blades will counter-balance the mass of opposite blades. It is quite possible that in obtaining true static balance, the length of one blade as compared to its adjacent or opposite blade may vary as much as ¼ inch.

(12) To protect the finished tips against moisture, each tip must be given an even coat of grade "A" white shellac, but care should be exercised when applying the shellac that true static balance is not disturbed. Under no condition should extra coating of shellac be applied to obtain final true balance.

(13) It is not advisable to use test propellers having a blade off track more than ⅛ inch as any propeller that runs out of track due to a warped blade can seriously upset dynamic balance.

(14) No filler of any kind should be used on tips, blade surfaces or screw holes to obtain static balance.

(15) The instructions given above will result in providing a propeller which will be suitable for the running-in of overhauled engines and will be sufficiently accurate to enable the operator to determine that the engine is functioning in a normal manner and within normal limits. It is impracticable to attempt the calibration of a test propeller as a means of checking horse power output accurately unless the engine power output is first checked on a dynamometer and all conditions corrected to standard atmospheric conditions which would then permit a given propeller to be calibrated and a propeller load curve drawn accordingly.

**TEST COWLS** A test cowl, Part No. 32723, is an essential part of testing equipment. The cowl is necessary to direct the air flow properly around the engine cooling surfaces. When using this cowl, it is necessary to use special corrugated rocker box covers on both intake and exhaust rocker box, Parts No. 32824 and 32825.

CAUTION: **If regular rocker box covers are used, the test cowl may slip forward into the propeller with resulting damage to the engine and propeller.**

**TESTING ENGINE ON A FIXED STAND**

Mount the engine on the test stand.

(1) These instructions apply particularly to the type of stand employing a stand propeller as a medium of absorbing engine power.

NOTE: A bronze mount must be used for attaching engine to a fixed type propeller stand.

(2) Use two chain hoists for lifting and maneuvering the engine onto the test stand.

(3) Attach the engine hoist sling (Tool No. 802552) on the rear hoist and lower the hoist so that the attaching bars may be fastened to the intake rocker box studs of No. 1 and 9 cylinders.

(4) Tighten all cable clamps.

(5) Install the lifting eye (Tool No. 80601) on the propeller shaft threads and attach a front hoist to the lifting eye.

(6) Support the engine weight on the hoist and detach the bronze engine mount from the engine assembly stand.

(7) Check the tightness of the bolts attaching the engine to the engine mount.

(8) After checking the tightness of the mounting bolts, raise the engine and secure the engine and mount assembly to the test stand by bolting it securely with the four large attaching bolts.

(9) Remove the engine slings and the propeller shaft lifting eye.

Attach Controls

(1) Connect manifold pressure gage to the intake manifold pressure connection on the supercharger front housing and insert a carburetor air temperature thermometer in the air scoop.

(2) Connect the throttle control.

(3) Connect carburetor fuel cut-off solenoid.

(4) Regardless of the model engine being tested, controls should be checked for full travel of the operating levers.

(5) Connect the magneto ground wires to the magneto terminals so that when the switch is in position "R" the left hand magneto is grounded and when it is in the position "L", the right hand magneto is grounded.

(6) Check the ground wiring of the switch to the engine stand.

(7) Connect the oil pressure gage line, oil supply line, and the oil scavenge line.

(8) Connect all thermometer connections.

(9) Connect the fuel feed and fuel pressure lines; the pressure being taken at the pressure connection provided at the carburetor.

(10) Connect the washer type thermocouple under the rear spark plugs on No. 1, 4, and 7 cylinders.

(11) Assemble short exhaust stacks or exhaust manifold to the cylinders.

(12) Connect lines to the fuel pump drain connection and the supercharger drain valve to carry the discharge well out of the area of the lower cylinders to avoid fire hazard.

(13) Clean the propeller shaft and propeller hub splines.

Mount the test propeller

(1) Mount the test propeller on engine as follows:

(2) Coat the propeller shaft threads lightly with Lubriplate No. 130A or other suitable antiseize compound.

(3) Coat the propeller shaft splines lightly with engine oil.

(4) Place the rear centering cone firmly against the thrust nut face and see that the tapered surface is clean, free from nicks or burrs and perfectly dry.

(5) Install the hub nut counting the turns to the bottom. Remove the nut and place the propeller shaft protector on the shaft. See figure 255.

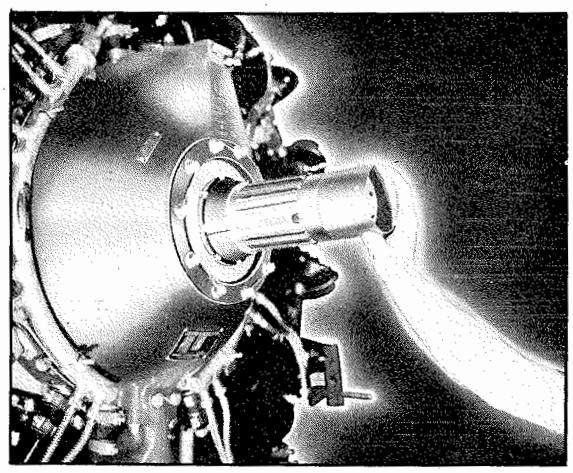


**Fig. 255. Installing Thread Protector**

(6) Install the propeller.

NOTE: Care must be taken not to damage the crankshaft threads when installing the propeller.

(7) Clean the split front centering cone, dry the tapered surface, and inspect for nicks or burrs.

(8) Install the propeller hub nut.

(9) Coat the threads of the propeller hub nut with Lubriplate 130A, place the front centering cone against the shoulder of the nut, and assemble both parts on the shaft. Tighten the hub nut. See figure 256. The number of turns must be not more than 1½ turns fewer than counted in Item (6). Similarly the minimum number of turns of the hub nut on the shaft must be not fewer than seven.

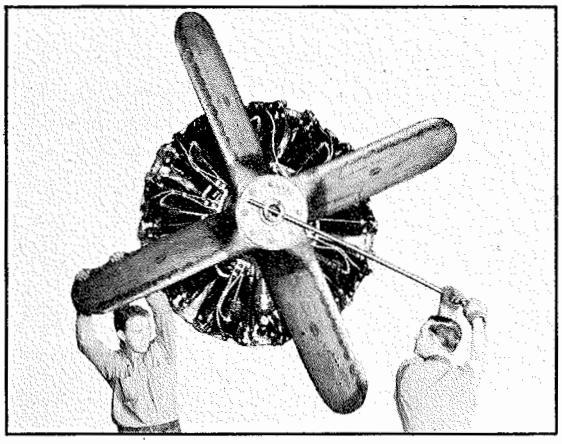


**Fig. 256. Tightening Propeller Hub Nut After Installing Propeller**

(10) Do not tighten the nut with a short bar and hammer; use a bar approximately 3 to 3½ feet long, made of a good grade of steel, and tighten the nut with a straight downward pull from a horizontal plane, applying a force on the end of the bar of 250 to 300 pounds. Lockwire the nut. See figure 257.

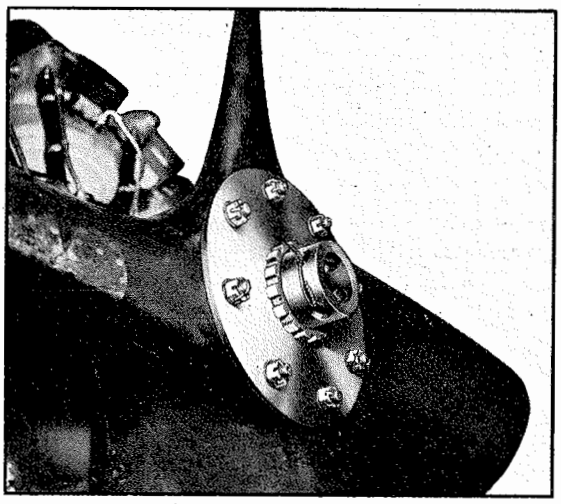


**Fig. 257. Lockwiring Propeller Hub Nut**

(11) Place the puller ring in the hub groove, install and cotterpin the locking pin.

(12) Install the starter and connect the starter cable.

Check connections.

(1) Open the main fuel supply valve and check all gas line connectios for leaks.

(2) Close the valve until the engine is ready to be started.

(3) After making certain that the magnetos are grounded, pull the propeller through at least four revolutions in the direction of rotation to make sure that all parts are free and that there are no restrictions in the cylinders.

**DURATION OF TEST** A three hour run-in in accordance with the following table is recommended for all engines after overhaul:

| Duration in minutes | Percent Rated Man. Pres. | Approx. Percent Normal Speed | Approx. Percent Normal Rated H.P. |
|---|---|---|---|
| 10 | 55 | 58 | 20 |
| 10 | 60 | 67 | 30 |
| 10 | 65 | 74 | 40 |
| 30 | 75 | 84 | 60 |
| 90 | 90 | 95 | 85 |
| 30 | 100 | 100 | 100 |

Following the 100% run the engine should be operated for two one minute periods at take-off manifold pressure and rpm, each preceded by a five minute interval at idling speed.

Two cycles of clutch shifts (four shifts at three minute intervals) should be made at not over 84% rated rpm on engines equipped with two-speed superchargers. Great care must be taken to avoid exceeding power and speed limits when the high ratio drive is engaged at sea level. When shifting into high it is well first to retard the throttle to reduce the manifold pressure about 3 in., then shift and readjust the throttle to obtain the 84% speed. Always allow five minutes to pass before reshifting to permit the clutch plates to cool.

CAUTION: **If a constant-speed type propeller is used as a test propeller the throttle must be retarded to maintain the same manifold pressure after the shift. Since the speed would remain constant with this type of propeller the pressure would rapidly increase as the shift to high ratio was made with immediate danger of seriously damaging the engine.**

Make corrections in horsepower at part throttle using the following formula:

$$\text{Corrected Horsepower} = \text{Observed Horsepower} \times \sqrt{\frac{460 + \text{Carburetor Air Temperature}}{460 + 60}}$$

$$\text{CHP} = \text{OHP} \times \sqrt{\frac{460 + \text{CAT}}{460 + 60}}$$

Note that the rated horsepower is based on full throttle operation corrected to 60 deg. C. A. T., zero vapor pressure and 29.92 in. Hg. dry air pressure at top deck of carburetor. Restrictions in the air supply system or the use of air cleaners will reduce the manifold pressure and power at wide open throttle conditions.

The engine should be checked for satisfactory idling.

The acceleration should be checked at the conclusion of the idling period. The engine should not stall when the throttle is opened quickly.

Check the rpm with 85% normal rated speed on propeller load and note the loss of revolutions when switched to one magneto at a time. When checking magnetos do not operate on one magneto for a period longer than necessary to determine its rpm loss. After checking the first magneto, allow the engine to operate on both magnetos for a short period before checking the second magneto.

See figures 258 and 259 for typical horsepower and fuel consumption curves.

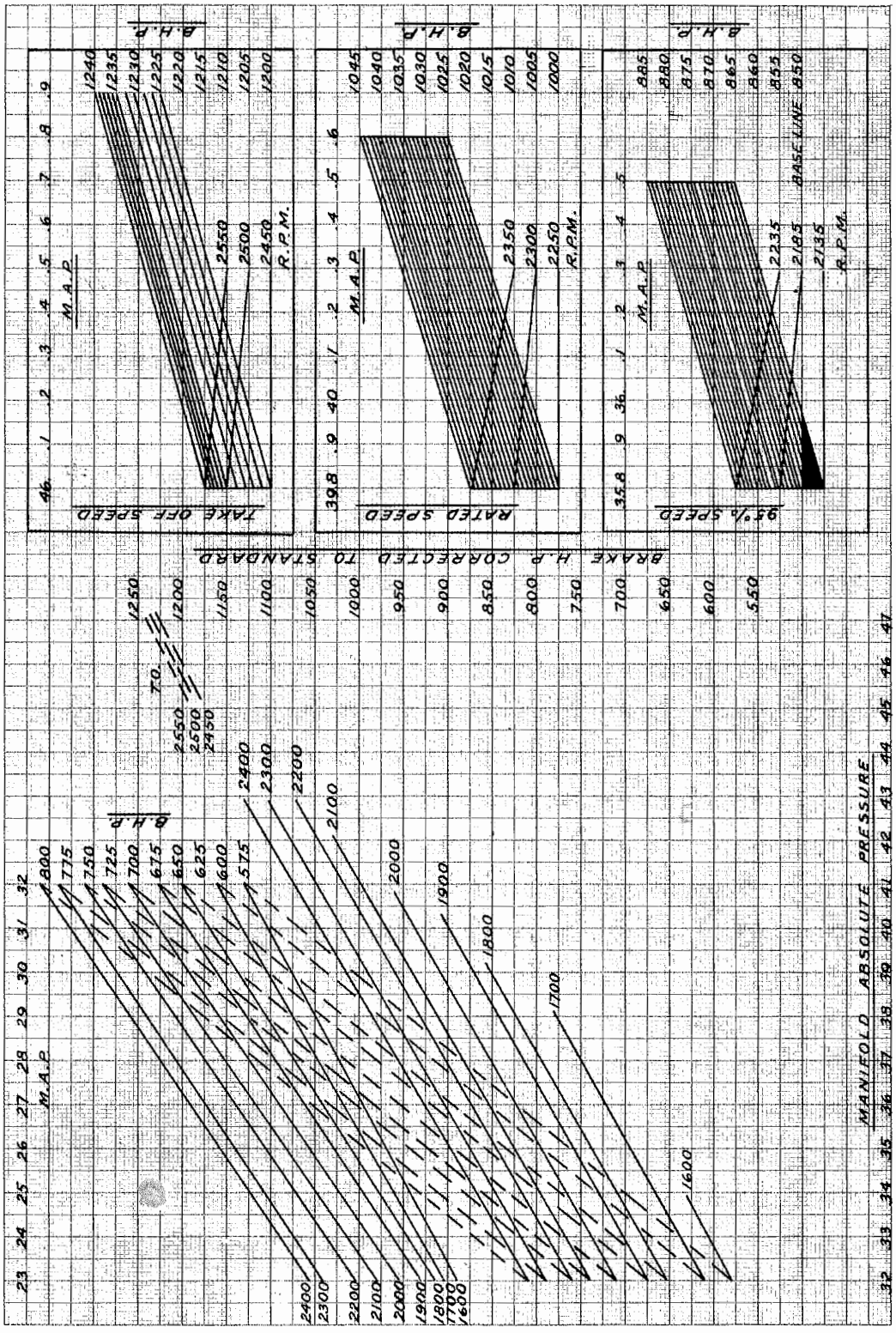



Fig. 258. Power Curve

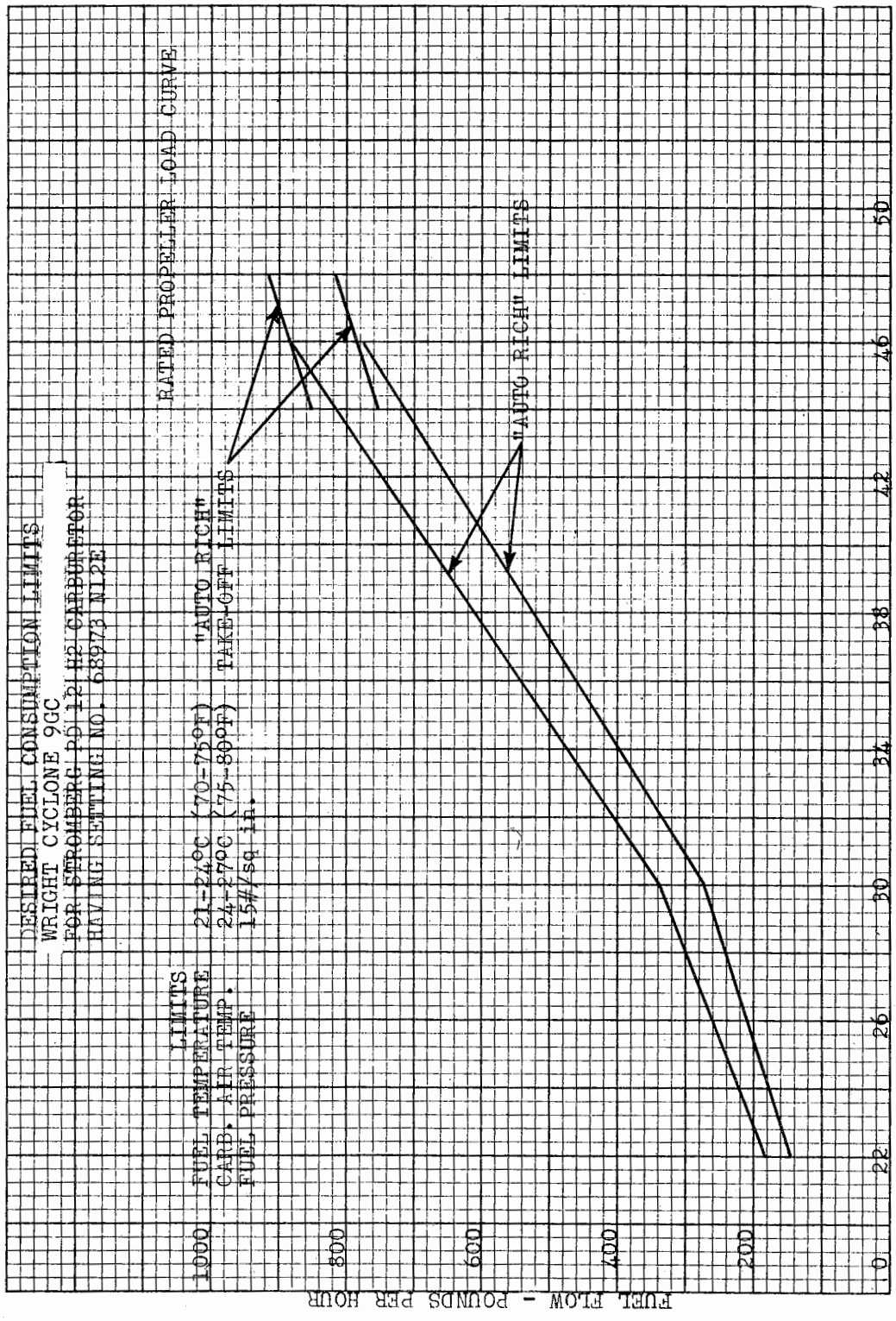



**Fig. 259. Fuel Curve**

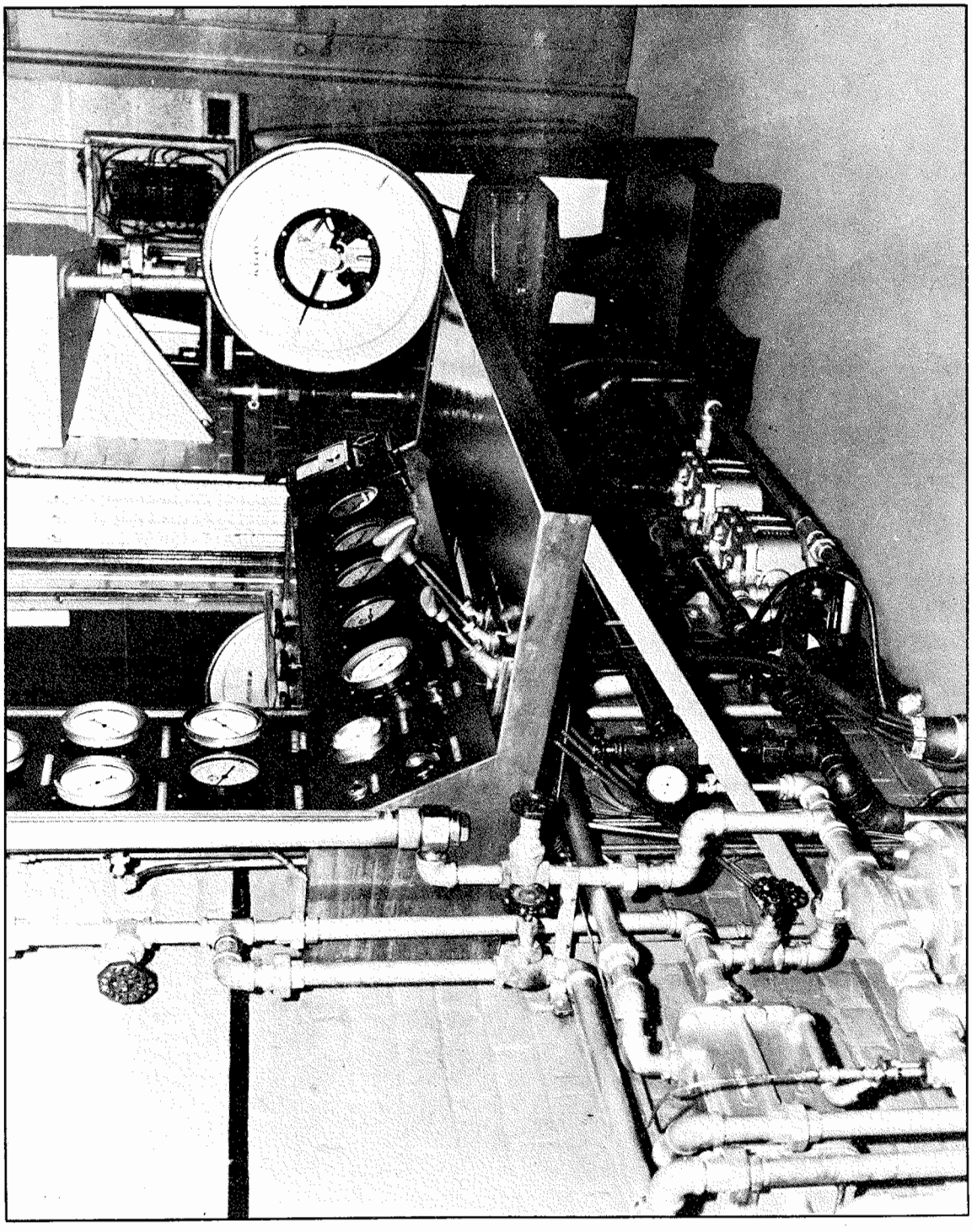


**Fig. 260. Test Control Room**

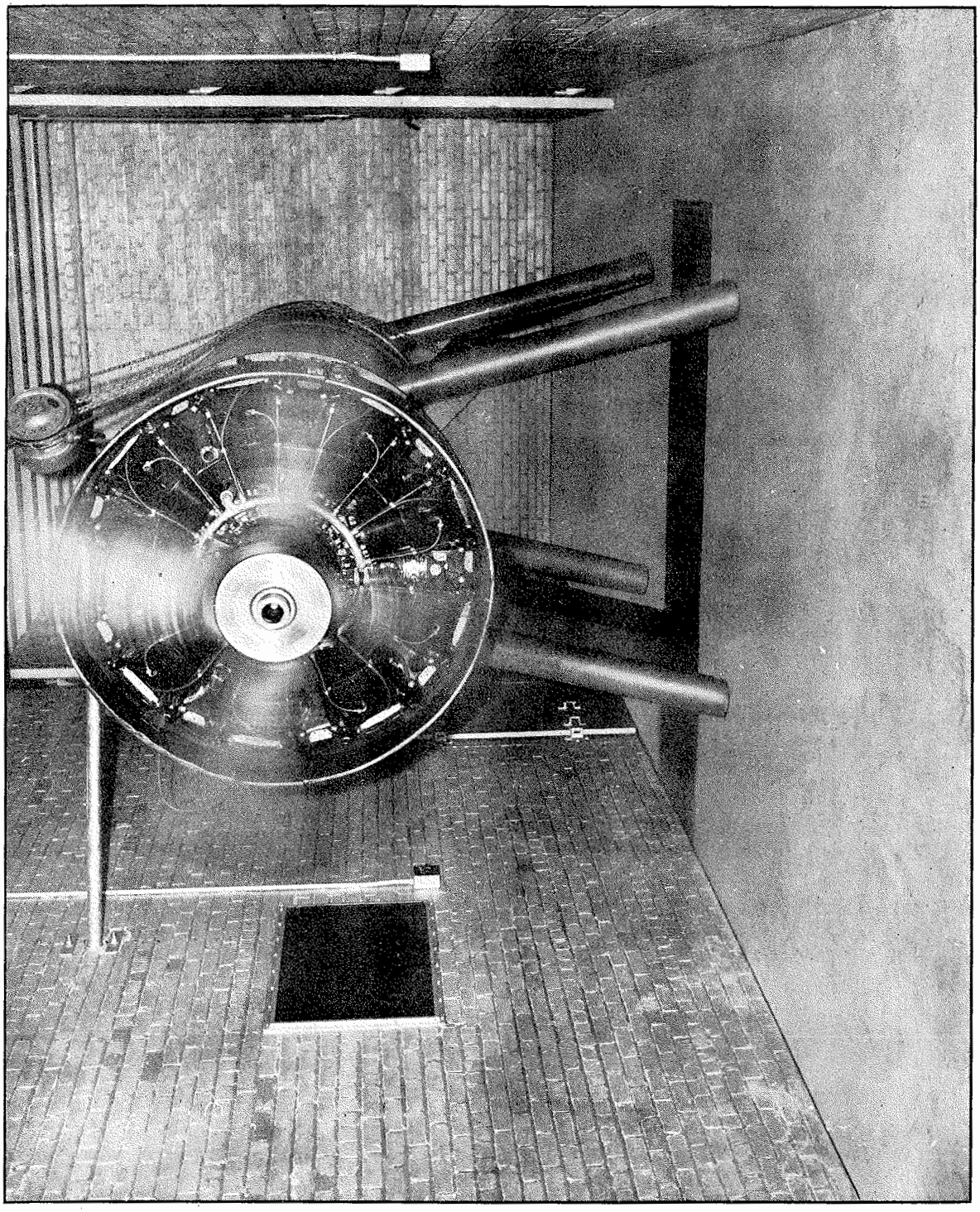


Fig. 261. Engine Test Cell

# TEST EQUIPMENT

The Wright Aeronautical Corporation has designed a series of test stands described below. The test stands described are suitable for the testing of double row and single row engines and may be started as an exposed installation and gradually built up to a complete, enclosed and soundproofed test house, or a complete test house may be built initially. Plans for these test stands may be obtained from the Wright Aeronautical Corporation, Service Division. Figure 260 shows a typical test house control room. An enclosed type-test cell is shown in figure 261.

The location of the test stand should be conveniently located with relation to the overhaul shop. When planning the location of the test stand it is suggested that due consideration be given for possible future expansion. It should also be determined whether a right or left-hand installation should be used. Space limitations may make this an important factor.

**EXPOSED TYPE TEST STAND** The exposed type test stand consists of a concrete foundation and the test stand assembly without building. A terminal box assembly and the thermocouple junction box assembly are also provided. Instruments, piping installations, and controls are not included in this type, but drawings on these installations may be procured under the specification for the plain type stand.

When requesting information and plans concerning the exposed type stand, order Assembly Specification No. 34059 for a right-hand installation and Assembly Specification No. 34341 for a left-hand installation together with the detail drawings involved. Sketches 262, 263, 264, and 265 show right-hand installations.

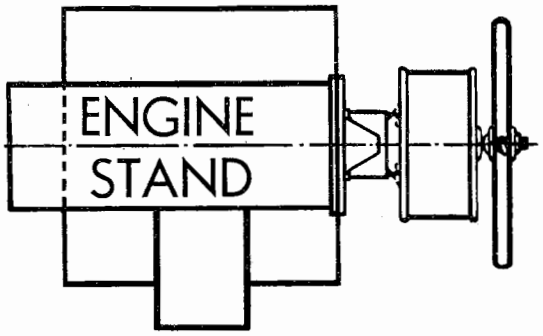



**Fig. 262. Exposed Test Stand**

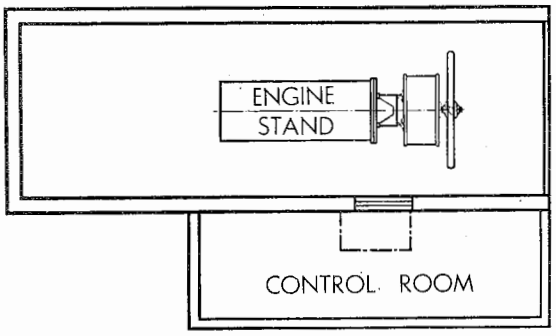



**Fig. 263. Plain Type Test House**

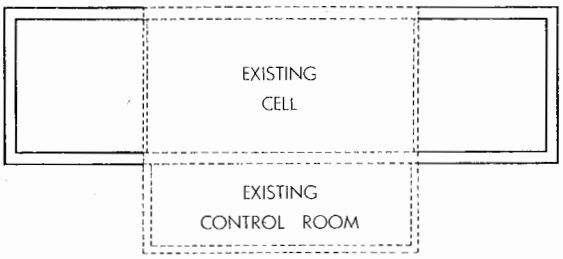



**Fig. 264. Sound Treatment for Plain Type Test House**

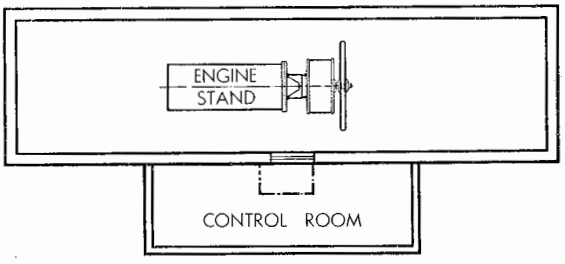



**Fig. 265. Sound Treated Test House**

**PLAIN TYPE TEST HOUSE** The plain type of test house is an enclosed installation. The test cell air intake and exhaust passages are horizontal, and no soundproofing is provided except the sound insulated observation window between the

control room and the test cell. A control room oil system provides heat exchangers and water and steam connections for the control of oil temperatures, tanks and scales for oil flow measurements and oil consumption checks, and a rotary hand pump for circulating the oil through the heat exchangers before starting the engine. A fuel cooler to eliminate danger of vapor lock is optional equipment.

Instruments and engine controls supplied provide for the following checks:

Fuel Flow
Engine RPM
Engine Oil Pressure
Oil Temperatures "IN" and "OUT" of Engine
Oil Temperature Out of Cooler
Front Section Temperature (Reduction Gear case)
Oil Pressure "HIGH" and "LOW" Clutch
Oil Pressure "HYDRO CONTROL"
Cylinder Head and Base Temperatures
Carburetor Air Temperature
Fuel Temperature
Fuel Pressure
Supercharger Pressure in Inches of Mercury
Rear Section Pressure in Inches of Water
Air Scoop Pressure in Inches of Water

When requesting information concerning the plain type test house, order Assembly Specification No. 34078 for the left-hand type and Assembly Specification No. 34077 for the right-hand type together with the detail drawings involved. The right-hand type includes a vertical air exhaust stack not soundproofed. The construction of this stack is optional. The stack may be constructed on the left-hand type in accordance with Assembly Drawings No. 34054 and 34055.

**ADDITION OF SOUND TREATMENT** Assembly Specification No. 34079 together with the detailed drawings were prepared in order that operators having plain type test houses with horizontal intake and exhaust could sound treat the unit if it became desirable or necessary at a later date. The specification provides for the addition of sound treated vertical air intake and exhaust stacks, the addition of soundproofing material to the test cell roof, and a soundproof door between the test cell and the control room.

**SOUND TREATED TEST HOUSE** The sound treated test house includes all the piping installations, instruments and controls listed for the plain type test house, but in addition, it includes sound treated vertical air intake and exhaust stacks and a sound treated test cell roof. The soundproof door between the test cell and control room is also provided. This type of test house is particularly desirable where noise may be disturbing to the working personnel or the immediate community.

When requesting information concerning the sound treated type of test house, order Assembly Specification No. 34023 for the right-hand installation and Assembly Specification No. 34076 for the left-hand installation together with the detail drawings involved.

# TEST INSTRUMENTS

The following discussion explains the purpose and the use of the several instruments needed for engine testing, and lists additional makers of instruments recommended by the Wright Aeronautical Corporation. If the operator constructs his test apparatus in accordance with the preceding test specifications, all instruments listed in the specifications should be used.

**MANOMETERS** A manometer is used to determine the amount of vacuum or pressure existing in the intake manifold of the engine. It consists of two glass tubes connected at the bottom or a single glass tube bent in the shape of a "U". The manometer is mounted in a vertical position and filled approximately half full of mercury. A scale graduated in inches and tenths of an inch is located between or in back of the tubes. The graduations start at zero in the center of the scale and extend fifteen inches above and below the zero mark. The

scale is provided with an adjustment that permits its being set so that the zero mark indexes with the level of the mercury when the tubes are open to the atmosphere. See figure 266.

In use, one end of the manometer is connected to the intake manifold or supercharger front section and the other is left open. As the engine is started it will be observed that the mercury in the side of the manometer connected to the intake manifold rises above the zero mark whereas the mercury in the other side drops an equal distance below the zero mark. The distance in inches between the two levels of the mercury represents the amount of manifold vacuum. As the speed of the engine is increased the vacuum decreases due to the wider throttle opening permitting a greater amount of air-fuel mixture to enter the engine intake manifold. As the engine speed is further increased the mercury in the side of the manometer connected to the intake manifold will drop below the zero mark and mercury in the other side will raise an equal amount above the zero mark thus indicating that pressure exists in the intake manifold. The distance between the two levels, in inches, indicates the amount of pressure, expressed in "In. Hg." (Inches of Mercury). One inch of mercury is equal to 13.6 Inches $H_2O$ (Inches of Water) (.491 lb./sq. in.).

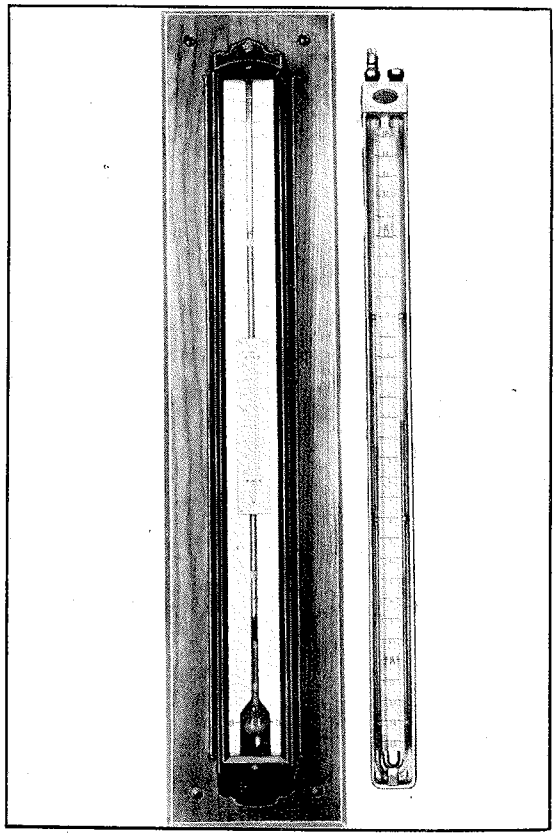


**Fig. 266. Barometer and Monometer**

The purpose of the supercharger is to force a greater weight of air-fuel mixture into the cylinders than would ordinarily be drawn in by the action of the pistons alone. This is accomplished by increasing the pressure and thus the density or weight per cubic foot of the mixture in the intake manifold. The normal action of the supercharger on engines of high supercharger gear ratio must be restricted at sea level or at low altitudes by closing the throttle and thus holding the pressure in the intake manifold to a specified value. Since it is necessary to restrict the manifold pressure of certain engines it is essential that the pressure be carefully measured. The manifold pressure should never be permitted to exceed the values given on the engine data plate for rated powers and maximum take-off power.

The manifold pressure figures given on the engine data plate are manifold absolute pressures for rated power and maximum take-off power. Manifold absolute pressure is the dry air barometric pressure in inches of mercury plus the observed manifold pressure in inches of mercury. The manifold pressure must be corrected for atmospheric temperature and moisture before being used to compute horsepower.

Manometers suitable for test purposes are manufactured by the Meriam Company, Cleveland, Ohio. These manometers may be obtained with a 30 inch (762 mm) U-tube, 30 inch (762 mm) scale graduated in inches and tenths (centimeters and millimeters) and a standard packing gland.

**BAROMETERS** A barometer is used for the determination of atmospheric pressure. It consists of a glass tube closed at the top and terminating at the bottom in a bowl open to the atmosphere. The tube is placed in a horizontal position, filled with mercury then moved to a vertical position which causes the mercury in the tube to

fall until a vacuum exists in the tube above the mercury. The level of the mercury in the bowl, being exposed to the atmosphere, is affected by variation in the pressure causing the column of mercury in the tube to rise or fall. The difference in inches between the level of the mercury in the bowl and the level in the tube represents the barometric pressure expressed in inches of mercury. See figure 266.

An instrument suitable for test purposes is manufactured by the American Gauge Company, Brooklyn, New York.

The true barometric pressure is the observed barometric pressure corrected for temperature to 32 deg. F. by subtracting the correction factor from the observed barometer reading. The correction factors are listed below opposite the observed atmospheric temperature:

| | Obs. Hg. in Inches | | |
|---|---|---|---|
| Temp. F. | 28 | 29 | 30 |
| 30 | .00 | .00 | .00 |
| 32 | .01 | .01 | .01 |
| 34 | .01 | .01 | .01 |
| 36 | .02 | .02 | .02 |
| 38 | .02 | .02 | .03 |
| 40 | .03 | .03 | .03 |
| 42 | .03 | .04 | .04 |
| 44 | .04 | .04 | .04 |
| 46 | .04 | .05 | .05 |
| 48 | .05 | .05 | .05 |
| 50 | .05 | .06 | .06 |
| 52 | .06 | .06 | .06 |
| 54 | .06 | .07 | .07 |
| 56 | .07 | .07 | .07 |
| 58 | .07 | .08 | .08 |
| 60 | .08 | .08 | .09 |
| 62 | .08 | .09 | .09 |
| 64 | .09 | .09 | .10 |
| 66 | .09 | .10 | .10 |
| 68 | .10 | .10 | .11 |
| 70 | .10 | .11 | .11 |
| 72 | .11 | .11 | .12 |
| 74 | .11 | .12 | .12 |
| 76 | .12 | .12 | .13 |
| 78 | .13 | .13 | .13 |
| 80 | .13 | .13 | .14 |
| 82 | .14 | .14 | .14 |
| 84 | .14 | .15 | .15 |
| 86 | .15 | .15 | .16 |
| 88 | .15 | .16 | .16 |
| 90 | .16 | .16 | .17 |
| 92 | .16 | .17 | .17 |
| 94 | .17 | .17 | .18 |
| 96 | .17 | .18 | .18 |
| 98 | .18 | .18 | .19 |
| 100 | .18 | .19 | .19 |

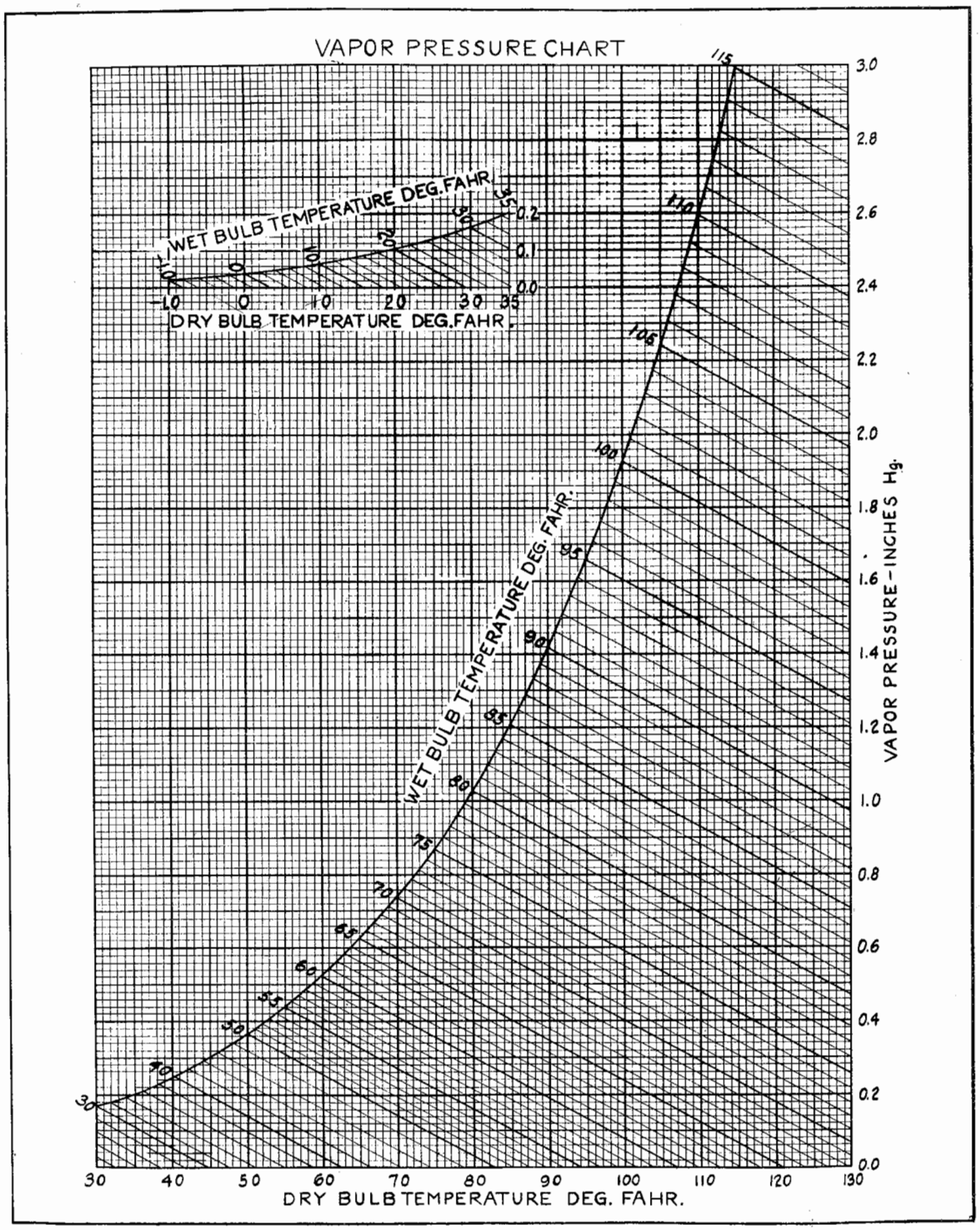



**Fig. 267. Vapor Pressure Chart**

The dry air barometric pressure is the true barometer corrected for vapor pressure according to the following formula:

B = B1 − O.

B = Dry air barometric pressure in inches mercury.

B1 = True barometer in inches mercury.

O = Aqueous vapor pressure in inches mercury.

**PSYCHROMETERS (WET AND DRY BULB THERMOMETERS)** The vapor pressure may be determined from the curve shown in figure 267. The wet and dry bulb temperatures in degrees Fahrenheit are obtained using a psychrometer.

A convenient type of psychrometer consists of a wet-bulb and a dry-bulb thermometer suitably mounted as a unit and fitted with a handle to provide the means by which it may be rotated. For most accurate readings the instrument should be rotated for a period of at least 30 seconds and the readings taken immediately thereafter.

An instrument suitable for test purposes is manufactured by the Taylor Instrument Company, Rochester, New York. NOTE: It is recommended that test instruments be periodically returned to their respective manufacturers for calibrating.

The psychrometer should be rotated rapidly by hand with the operator standing in the shade and facing the wind. It should be rotated for at least thirty seconds and the temperatures then observed quickly. The wet bulb temperature should be taken first. Three readings should be made and the average used to obtain the vapor pressure. The wet bulb temperature is read downward on the diagonal line of the above chart to a point where the dry bulb temperature, read on a vertical line, intersects. From this point read the vapor pressure directly across on the horizontal line.

An example for determining manifold absolute pressure under observed conditions of 29.86 inches Hg. observed barometer at 84 deg. F., dry bulb temperature of 78 deg. F., wet bulb temperature of 68 deg. F. and manifold pressure manometer reading at 5 inches Hg. is as follows:

| | |
|---|---|
| Obs. Bar. 29.86 inch Hg. | 84 deg. F. |
| .15 inch | Corr. factor for temp. (84 deg. to 32 deg. F.) |
| 29.71 inch Hg. | True barometer |
| 0.58 inch Hg. | Vapor pressure |
| 29.13 inch Hg. | Dry air barometric pressure |
| 5.0 inch Hg. | Manometer pressure |
| 34.13 inch Hg. | Manifold absolute pressure |

**TACHOMETERS** For test purposes it is recommended that a tachometer embodying a counter be used in order that an accurate check of the engine rpm can be obtained. When it is desired to check the engine speed, as for example at the beginning of each period of increased engine rpm, the counter is started simultaneously with a stop watch. At the moment when one minute has elapsed the counter is stopped. The reading of the counter prior to the check is subtracted from the number indicated on the counter at the end of the check and the difference multiplied by ten represents the number of revolutions per minute. If a more accurate count is desired readings of two or three minutes may be taken. See figure 268.

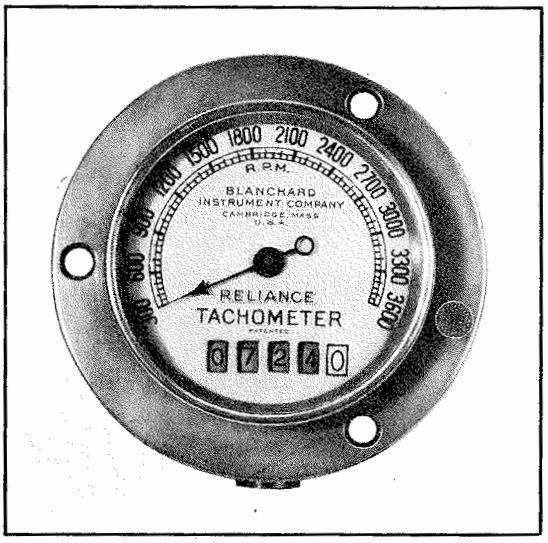



**Fig. 268. Tachometer With Counter**

A tachometer suitable for test purposes is manufactured by the Blanchard Instrument Company, Cambridge, Massachusetts. The

dial indicates from 300 rpm to 3600 rpm graduated in hundreds.

**PRESSURE GAGES** The fuel pressure gage should register from 0 to 50 pounds per square inch (0 to 3.5 kg./sq. cm.) with dial scale graduated in ½ pound (0.03 kg./sq.cm.) increments.

The oil pressure gage should register from 0 to 150 pounds per square inch (0 to 10.54 kg./sq.cm.) with dial scale graduated in 5 pound (0.35 kg./sq.cm.) increments.

Gages suitable for the determination of fuel and oil pressures are manufactured by the American Gauge Company, Brooklyn, New York, or the U. S. Gauge Company, New York City, New York.

**MAGNETO SWITCH** Airplane-type magneto switches may be used for test work. A suitable switch is the Model EA right and left hand manufactured by the Scintilla Magneto Company, Sidney, New York. Connections are made in accordance with markings at the terminals; that is, R.H. to right hand magneto, L.H. to left hand magneto, ground to ground and booster to booster.

**THERMOMETERS** Distance type thermometers used for the determination of "OIL-IN", "OIL-OUT" and carburetor air temperature should be mercury actuated with approximately a three inch bulb and a union connection having a one inch pipe thread. The dial should be graduated in units of 2 deg. from 0 deg. to 350 deg. F. These instruments are manufactured by the Taylor Instrument Company, Rochester, New York; C. J. Tagliabue Manufacturing Company, Brooklyn, New York; and the American Gauge Company, Brooklyn, New York.

**THERMOCOUPLE TEMPERATURE INDICATORS, PYROMETERS** Engine temperature indicators are necessary in order that the operator may determine operating temperature and conditions. There are several types of instruments adaptable to this use. The types used as regular aircraft equipment may also be used for testing although they are not quite as satisfactory as thermocouple pyrometers. These instruments are more rugged and embody features that are not found on the aircraft instruments. The principle of operation of both instruments is practically the same. The theory upon which their operation is based is as follows:

If two wires of dissimilar metal are joined together and the junction, known as the thermocouple, is located at a point on the engine that will cause the temperature of the thermocouple to rise, the temperature creates on EMF (electric-motive force) at the thermocouple. The instrument used to measure this force is a milli-voltmeter carefully calibrated to indicate in degrees. It is necessary that the type and length of thermocouple wire be used that is intended and determined by prior calibration, for the particular instrument.

As it is usually desired to know the temperature at various points on an engine, thermocouples are located at these points and connected through leads to a selector switch, thence to the indicating instrument. This eliminates the necessity of an instrument for each thermocouple. See figure 269.

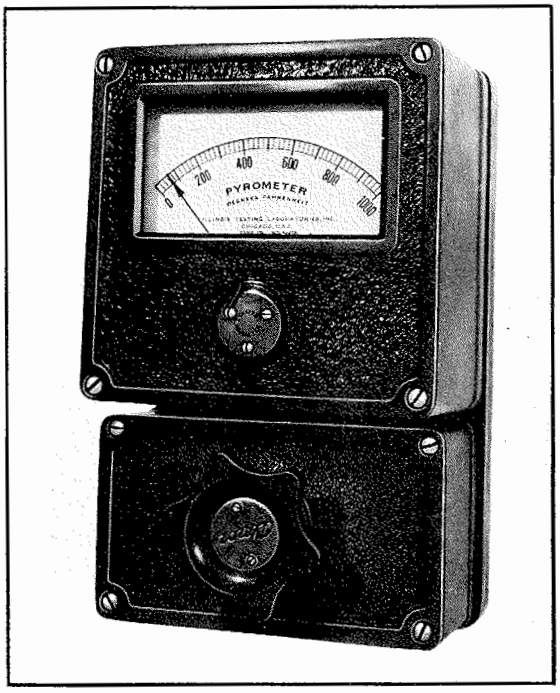



**Fig. 269. Thermocouple Pyrometer**

Thermocouple pyrometers are manufactured by the Lewis Engineering Company, Naugatuck, Connecticut; the General Electric Company, Schenectady, New York; Weston Electric Company, Newark, New Jersey; and Leed and Northrup Company, Philadelphia, Pennsylvania.

An electric pyrometer with dial graduated in units of 20 deg. from 0 deg. to 1000 deg. F. is manufactured by the Illinois Testing Laboratories, Chicago, Illinois. "ALNOR" model "RB"—8 circuit wall type, calibrated for 30 feet No. 14 Iron and Constantan Wire, will be suitable for all test requirements.

**HYDROMETER** Hydrometers for testing specific gravity of fuel should have a range of 0.650 to 0.700 and 0.700 to 0.750. Taylor instruments No. 22246 and No. 22245 respectively, are manufactured by the Taylor Instrument Company, Rochester, New York.

## CHAPTER VIII

# SLUSHING AND PACKING

IT is recommended that the procedure outlined in this chapter be adhered to in the treatment of all engines which have been overhauled and tested, except in cases where the engine is to be prepared for immediate installation in an airplane. Any engine that will not be run immediately after it is overhauled and tested should be slushed.

**ENGINE RUN-OUT AND INITIAL SLUSHING** (1) Use unleaded 65 or 73 octane fuel for the engine run-out.

(2) At the same time, use slushing mixture, AMS 3072, in place of lubricating oil.

(3) Either drain and refill fuel and oil tanks, or use auxiliary tanks for (1) and (2).

(4) Run the engine for fifteen minutes at 1000 rpm with the propeller in "LOW PITCH".

(5) Increase the rpm to 1200 and at the same time spray slushing mixture, AMS 3072, into the induction system either through the carburetor or through a connection in the carburetor adapter. Continue to run the engine until heavy smoke from the slushing oil is coming from all exhaust stacks.

(6) Stop the engine by placing the mixture control in "CUT OFF" position and move the throttle to the full "OPEN" position. Turn the ignition switch to the "OFF" position. The entire aspirating operation (5) and (6) should take only a few seconds.

(7) As soon as the engine stops, remove the front spark plugs from all cylinders.

(8) Install vented dummy plugs.

(9) Drain the oil from the sump.

(10) Install the crankcase dehydrating plug.

(11) Remove the exhaust stacks, slush the exhaust ports, and cover with moisture resistant seals.

(12) Remove the rocker box covers and coat the rocker arm assembly and cover with slushing mixture, AMS 3072. Reinstall the cover.

**ADDITIONAL SLUSHING** (1) Remove the carburetor and seal the induction passage.

(2) Mount the engine on an assembly stand.

(3) Inject a few teaspoonfuls of hot (175 deg. F—225 deg. F.) slushing mixture, AMS 3072, through the spark plug holes into each combustion chamber. The crankshaft must not be rotated after this procedure has been accomplished. If, however, the crankshaft is rotated, this procedure must be repeated.

(4) Remove the vented dummy spark plugs and install regular spark plugs. Connect the ignition leads to the spark plugs.

(5) Enclose the magnetos with an oil-resistant envelope and wash the engine thoroughly with a wash gasoline. Dry the engine with compressed air.

(6) Remove all the spark plugs and install cylinder dehydrating plugs. Connect the ignition leads to the dehydrating plugs using spark plug terminal protectors and connections. See figure 270.

**PACKING PROCEDURE** (1) Cover all breathers and vents with moisture resistant seals. See figures 271 and 272.

(2) If any accessories are removed from the engine, coat the accessory mounting pad recesses with slushing mixture, AMS 3072, and seal the pads securely with moisture resistant gaskets and substituting covers.

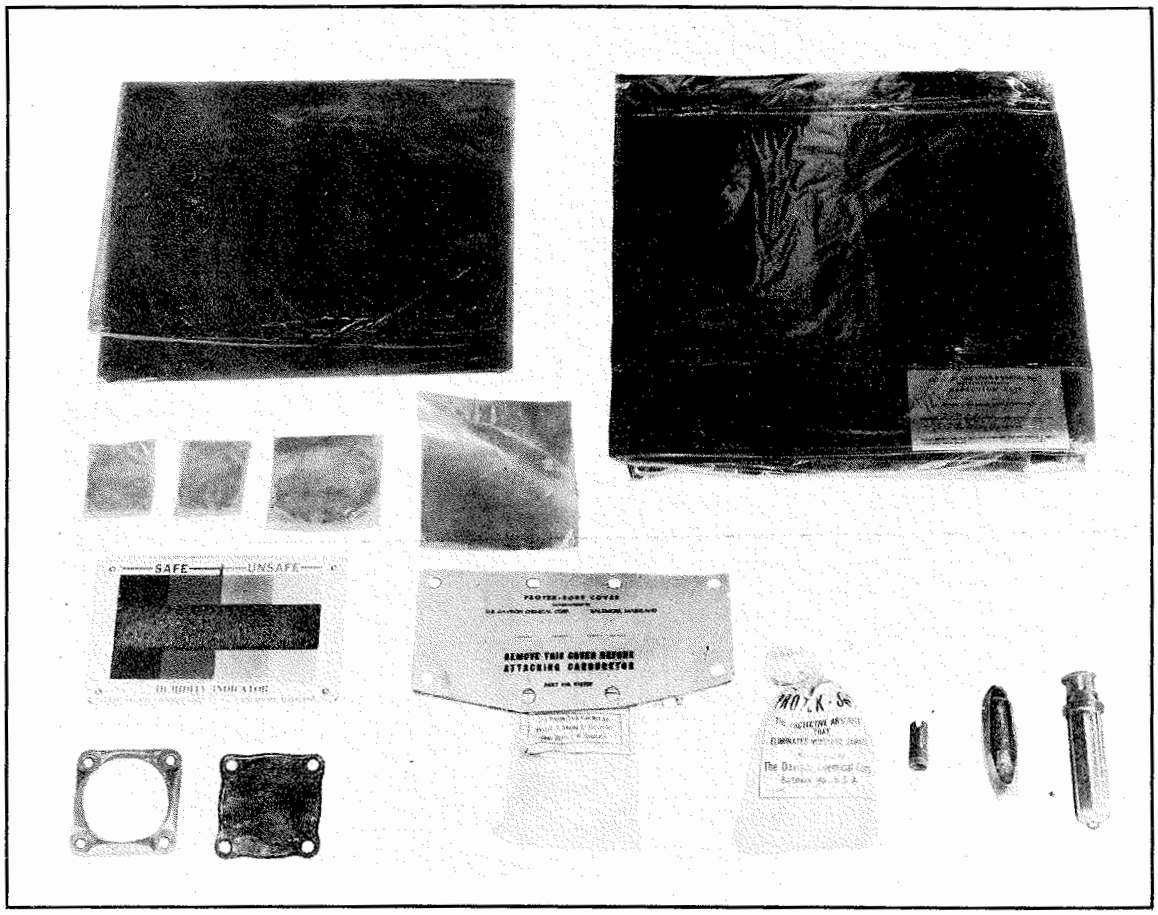



**Fig. 270. Engine Packing Equipment**

(3) Install the gasket and dehydrator bag assembly on the carburetor mounting pad and seal the induction passage tightly with a moisture-resistant seal.

(4) Install the oil tank vent sump to the oil tank vent connection on the supercharger

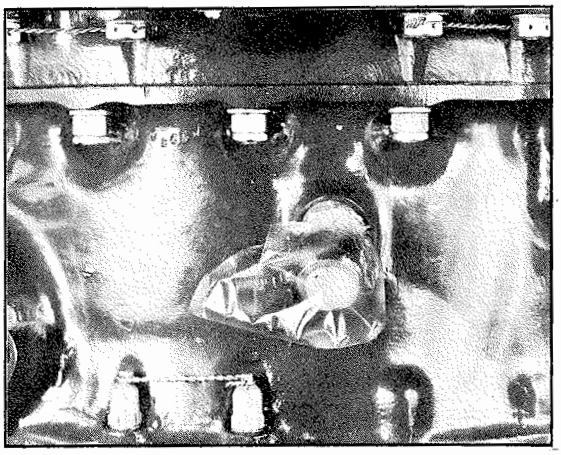


**Fig. 271. Location of Synthetic Rubber Cover on Supercharger Drain Valve**

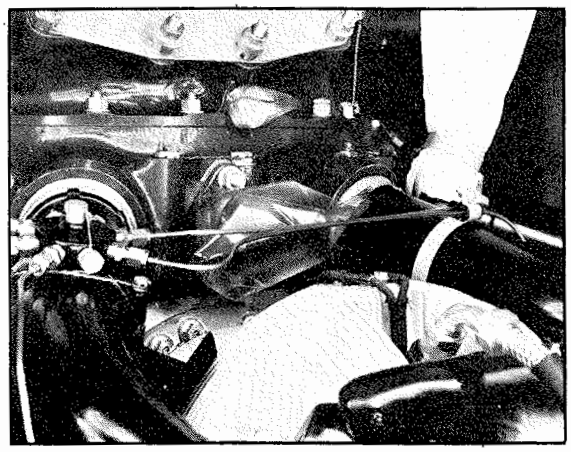


**Fig. 272. Location of Synthetic Rubber Cover**

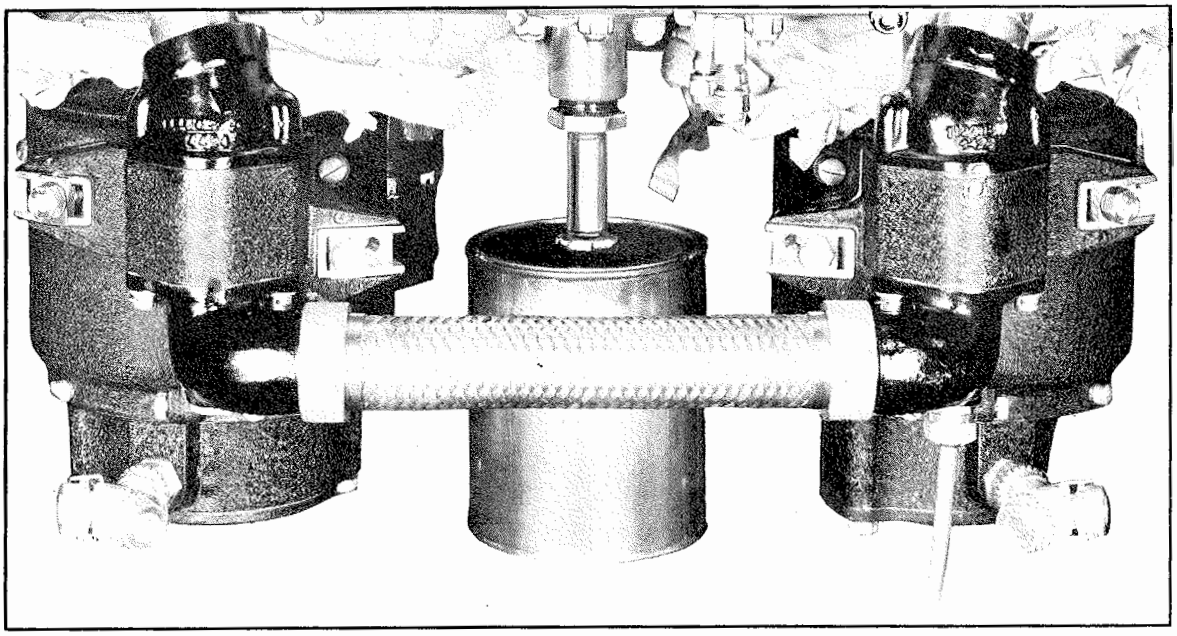


**Fig. 273. Location of Oil Tank Vent Sump**

rear housing cover. See figure 273. Lockwire the removed plug to any nearby location.

(5) Lift the plastic-film envelope over the supercharger rear housing, attach the engine plastic-film envelope to the cylinders, and secure the mounting plate to the engine.

(6) If large quantities of engines are stored, it is recommended that a stand similar to that shown in figure 274 be constructed. If this type stand is used, place the mounting plate on the stand and attach the plastic film envelope to the plate so that the gaskets in the envelope are located over the holes in the mounting plate, then lower the engine on to the mounting plate. See figure 275.

(7) Lower the engine and attach the mounting plate to the cradle of the shipping box. See figure 276. Remove the hoist and lifting eye and replace with the thread protecting cap.

(8) Coat the propeller shaft internally (AMS 3075) and externally (AMS 3072), wrap a grease-proof wrapper around the shaft and secure with adhesive tape.

(9) Arrange one lb. of dehydrating agent for each cylinder around the engine. Secure the bags to any available location so that the bags will not chafe the plastic film envelope during shipping. See figure 277.

(10) Wrap heavy paper or oil cloth around the circumference of the engine at the cylinder heads and place the humidity indicator chart between the plastic-film envelope and the wrapping, so located as to be clearly visible from the inspection port in the shipping box cover.

(11) Roll the plastic film envelope up over the propeller shaft and heat seal the envelope.

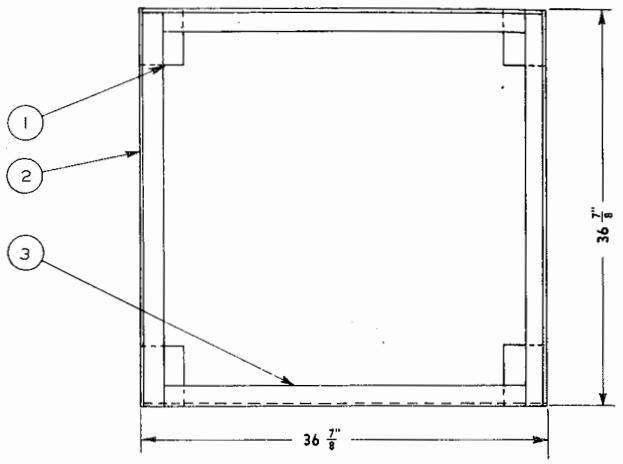
(12) Deflate the envelope just before the sealing operation is completed. See figure 278.

(13) Inspect to see that no ruptures of the envelope have occurred. A ruptured envelope must be repaired. Refer to the general instructions at the end of this chapter.

(14) After slushing and packing the accessories, as described in this chapter, lower the shipping box cover to the cradle and secure the cover to the cradle with the four bolts.

**SLUSHING AND PACKING OF ACCESSORIES CARBURETOR**

(1) Drain the carburetor by removing the ⅛ in. pipe plugs in the bottom of the regulator unit and by removing the external fuel line which is connected to the fuel control body See figures 279 and 280. Fill with lubricating oil, AMS 3070. Under no circumstances will the regulator air chambers, and passages, and/or automatic mixture control be slushed with oil; these plugs must be kept dry at all times. Drain the excess oil and replace the 1 in. pipe plugs. No air pressure shall be used to clean carburetors. When the carburetor is shipped detached from the engine, lock the throttle so that it cannot be moved. Wipe the carburetor clean and attach a ½ lb. bag of dehydrating agent to the car-




| MATERIAL LIST | | | |
|---|---|---|---|
| NO. | REQ. | DESCRIPTION | MAT'L |
| 1 | 4 | 4"X5 1/2"X 1/4" PLATE | ST. |
| 2 | 3 | 2"X2"X 5/16"L | ST. |
| 3 | | 2"X2"X 1/4"L | ST. |
| 4 | 14 | 6"X6"X 1/4" GUSSET | ST. |
| 5 | 4 | BOND CASTER 1640-A-4 WITHG-7 TIRES | |

NOTE:
WELDED CONSTRUCTION

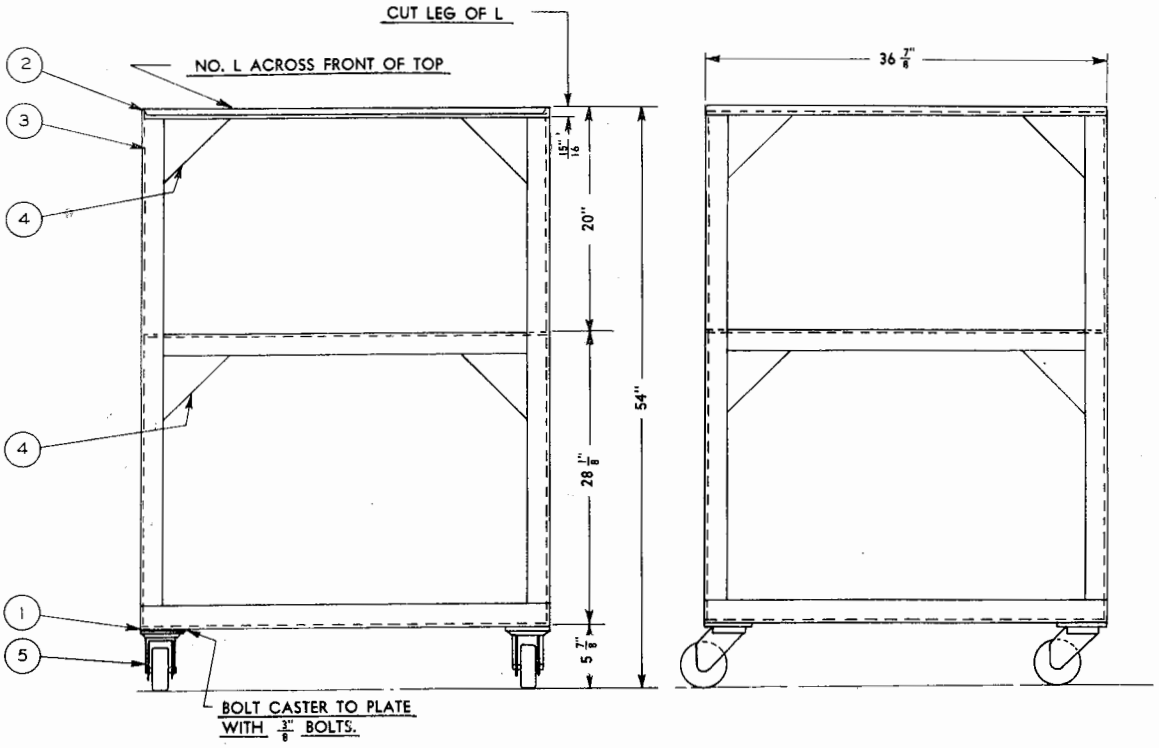



**Fig. 274. Portable Stand Dimensions**

buretor and seal the carburetor in a plastic film envelope. See figure 281. Pack the carburetor in the cover of the shipping box.

**FUEL PUMP** (1) Slush the fuel pump, either attached to or removed from the engine, by attaching a funnel on a rubber hose of approximately ¾ in. inside diameter to the inlet of the fuel pump. Pour approximately a pint of oil, AMS 3070, into the funnel while turning the shaft through several revolutions in the normal direction of rotation. Allow the oil to drain from the fuel pump outlet.

**OTHER ACCESSORIES** (1) Pack the generator, starter, fuel pump, magnetos, spark plugs, and all other accessories which have been removed from

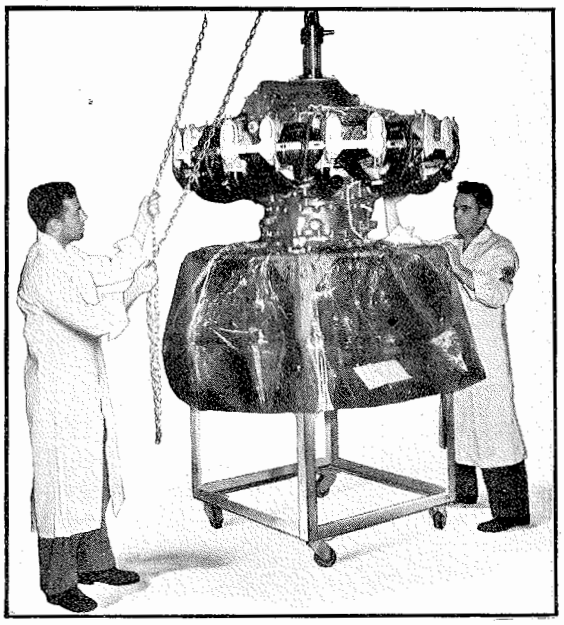


**Fig. 275. Lowering Engine Into Portable Stand**

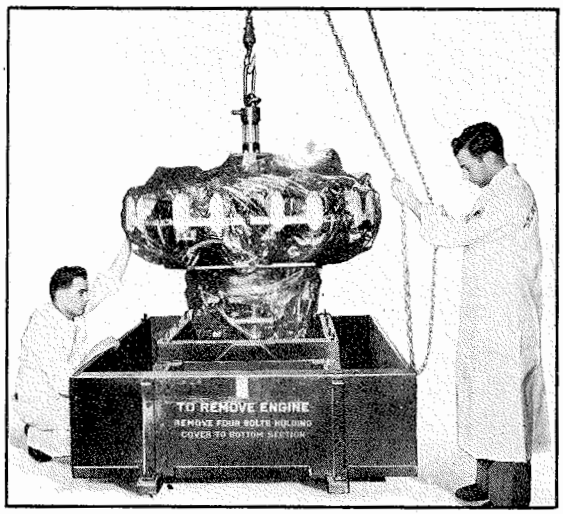



**Fig. 276. Lowering Engine Into Shipping Box**

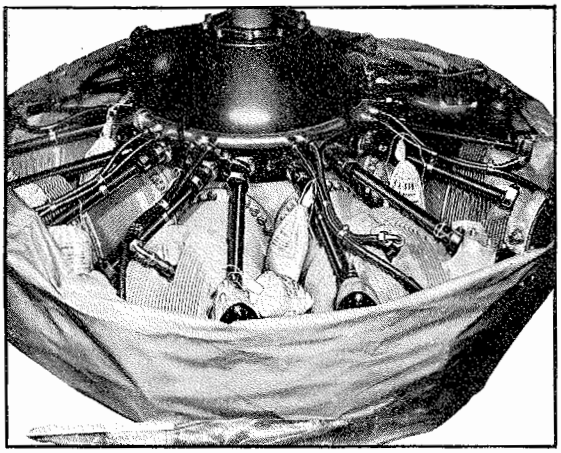


**Fig. 277. Location of Dehydrating Bags attached to Cylinder**

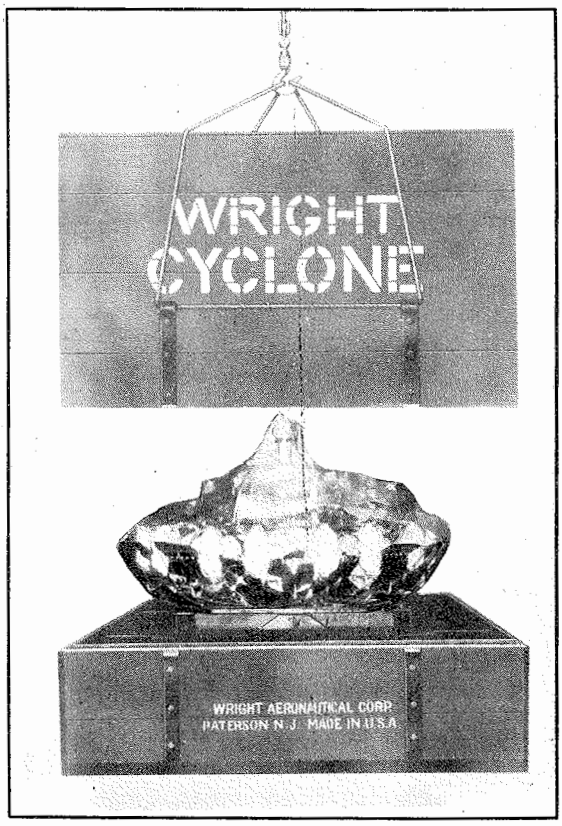



**Fig. 278. Engine Prepared for Storage**

the engine in individual plastic-film envelopes with a ½ lb. bag of dehydrating agent for each envelope. Care must be taken not to chafe or break the envelope. Secure the accessories and unattached parts, such as engine sling, tool kit, etcetera, in the cradle of the shipping box.

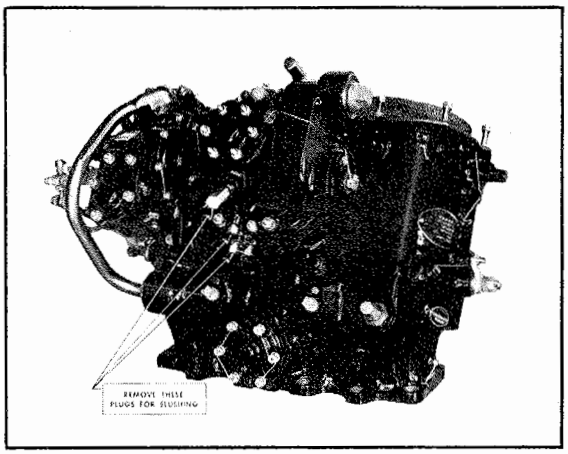



**Fig. 279. Drain Plugs Bendix Stromberg Carburetor**

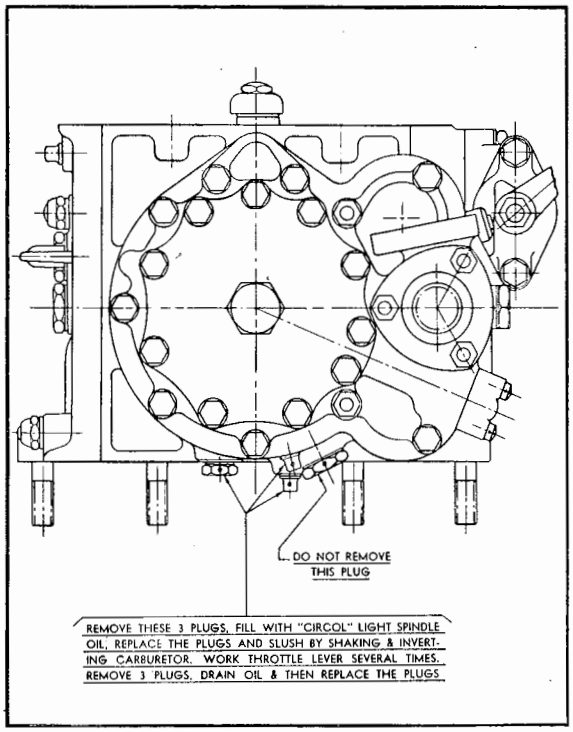

DO NOT REMOVE THIS PLUG
REMOVE THESE 3 PLUGS, FILL WITH "CIRCOL" LIGHT SPINDLE OIL, REPLACE THE PLUGS AND SLUSH BY SHAKING & INVERTING CARBURETOR. WORK THROTTLE LEVER SEVERAL TIMES. REMOVE 3 PLUGS, DRAIN OIL & THEN REPLACE THE PLUGS

**Fig. 280. Method of Slushing Holley or Chandler Evans Carburetor**

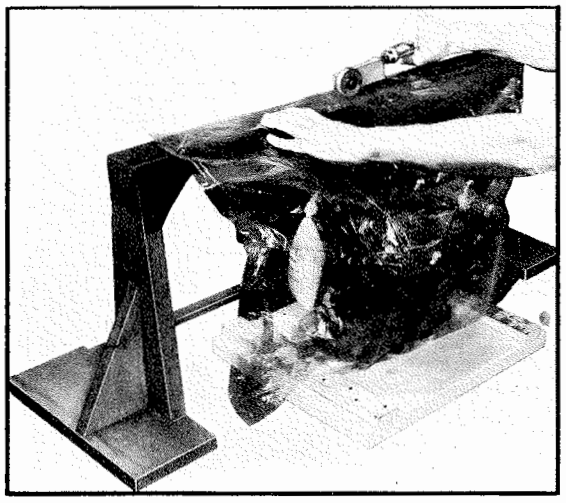


**Fig. 281. Sealing Plastic Film Carburetor Envelope**

# GENERAL INSTRUCTIONS

**PERIODIC INSPECTION AND RETREATMENT OF STORED ENGINES** The engine humidity indicator will be inspected at least semi-monthly for the first six weeks following preparation, and monthly thereafter to determine the color of the silica-gel contained therein. Under unfavorable climatic conditions, the humidity indicator will be inspected each week for the first six weeks; thereafter once each two weeks. Experience will dictate the frequency of this inspection. If the color of the silica-gel corresponds to those shown as safe on this indicator, no further treatment is necessary. If the color of the silica-gel corresponds to those shown as unsafe, the following procedure will be employed:

(1) Remove the engine shipping box top.

(2) Carefully cut the seam at the top of the engine envelope in such a manner as to remove the least possible amount of material. The temperature should be 70 deg. F. or higher when handling the plastic film.

(3) Carefully roll the engine bag down from the engine.

(4) Replace the dehydrator bags with fresh bags, and replace humidity indicator. Engine cylinder and crankcase dehydrator plugs will be replaced if in "unsafe" conditions.

(5) Bring the engine envelope back over the engine and reseal. The engines should require no other treatment than the periodic replacement of the dehydrator bags and plugs to insure adequate protection from atmospheric corrosion.

**BREAKAGE OF DEHYDRATING AGENTS** If any of the dehydrating agent containers is damaged while they are installed in an engine and any of the dehydrator agent has fallen into the engine, that part of the engine must be disassembled and cleaned before the engine is operated. These instructions also apply for carburetors.

**DEHYDRATOR SEALS** No dehydrating agent should be removed from its container and no dehydrator seals shall be removed until immediately prior to its installation. If the dehydrating agents are exposed to air for more than a few minutes before installation, the agent must be discarded.

**MAINTENANCE OF THE PLASTIC FILM ENVELOPE** It is recommended that the plastic-film envelope be kept at a temperature of 70 deg. F. or above. All work with plastic film should be done at or above this temperature. To seal the envelope, bring the open edges of the envelope together over the top of the engine, and, using the sealing iron at 325 deg. F. to 350 deg. F. seal the two edges of the envelope over a ½ in. wide area about ¼ in. from the edge of the cut.

A board covered with cardboard may be used to back up the plastic-film when the iron is run over it. A well-vulcanized seam will be transparent throughout the length of the seam, but a poor seam, in which the iron was not the right temperaure or the surfaces were not pressed together, will be cloudy or filmy. A poor seam should be repaired by repeating the operation more slowly until the seam is transparent. Care must be taken not to cut the plastic-film with too hot an iron.

There will be sufficient material in the upper part of the envelope so that the sealed edge can be cut off when the engine is removed. This excess material permits the envelope to be used five or six times.

After the sealing is finished, fold the excess material around the engine and secure it with tape so that there shall not be more than one thickness of envelope film between the humidity indicator and the inspection port in the side of the case.

Whenever a failure occurs that will permit the entrance of moisture into the plastic film envelope, the envelope may be resealed with the sealing iron following the procedure previously described or by resealing with any moisture-resistant sealing tape. Careful inspection should be made of the humidity indicator following the repair of a failure, to ascertain whether or not the moisture within

the envelope has increased to the danger point.

**EQUIPMENT** The following equipment is recommended for use in preserving engines for shipment or storage.

(1) Pressure gun.
(2) Carburetor mounting washer.
(3) Plastic-film shipping envelope.
(4) Plastic-film carburetor envelope.
  (a) Stromberg
  (b) Holley
(5) Carburetor adapter gaskets and moisture absorbent bag assembly.
(6) Cylinder dehydrator plugs.
(7) Spark plug terminal protectors and cable attachment.
  (a) ⅝ in. thread
  (b) 9/16 in. thread
(8) Crankcase dehydrator plugs.
(9) Humidity indicator.
(10) Dehydrator agent, Protek-Sorb (Silica-Gel)—½ lb. bags.
(11) Engine opening sealing envelopes.
(12) Oil tank vent sump.
(13) Exhaust pipe flange gasket (shipping or storage).
(14) Heating iron for sealing plastic-film bags.
(15) Engine slushing mixture.
(16) Carburetor slushing mixture.

The dehydrator bags contain activated silica-gel crystals which absorb moisture. The degree of activity of the crystals may be determined only by referring to the relative humidity chart which indicates humidity conditions. The crystals in the bag are not color-treated.

The cylinder dehydrator plugs which are used in the spark plug holes consist of transparent containers filled with silica-gel crystals and threaded at the end. The crystals are cobalt blue when freshly activated. As the silica-gel crystals absorb moisture, the color of the crystals changes from cobalt blue to light blue, to deep pink to light pink.

The humidity indicator is a five by eight inch chart upon which are printed two permanent color strips, one on each side of a transparent section filled with silica-gel crystals. These permanent color strips are divided into sections from left to right: deep blue, light blue, deep pink, and light pink. The crystals are deep blue when freshly activated and change in color as they absorb moisture. It is the purpose of this indicator to show the change of relative humidity in the engine envelope, so that the condition within the engine envelope may be determined. As the crystals match with the permanent color, the humidity within the engine envelope may be determined as safe or unsafe. When the crystals can be matched with dark pink or light pink sections or when the indicator shows an excess of 20 per cent, the dehydrating agent must be changed as described in these instructions.

## TREATMENT OF ENGINE AFTER WATER SUBMERSION

The problem of preventing corrosion or rusting of engine parts is comparatively simple when it is necessary to deal only with the effect of atmospheric moisture on steel. If, however, an engine through mishap has been submerged in either salt or fresh water the problem of arresting corrosion becomes exceedingly difficult and precautions correspondingly more necessary.

Guarding against the effect of atmospheric moisture has been treated in an earlier chapter entitled SLUSHING ENGINES, in which is explained the method used for preventing corrosion when such action has not already started. However, in the case of an engine which has been submerged the problem then is to stop corrosive action that has already started, and prevent any further corrosion. In order that the reasons for the method employed may be better understood the following brief discussion of corrosion is offered.

There are many factors that influence the rate of corrosion such as the condition of the atmosphere, the temperature and the material involved. The more humid the atmosphere the higher the rate of corrosion. Also, corrosion

is accelerated by higher temperatures, although this may be linked to the former owing to the fact that air at higher temperatures can carry a greater amount of moisture. The nature of the material also has a great influence on the rate of corrosion.

The information required to prevent or arrest corrosion may be gained from these facts. As this section is intended to deal solely with the treatment after submersion, recommendations covering this subject only will be given. It can readily be understood from the foregoing, that, first the water must be removed from all parts and secondly, if this is not possible, the parts must be so treated as to prevent contact with the atmosphere. In the case of a complete engine it is extremely difficult to accomplish this first provision, due to the inaccessibility of the parts. A complete tear-down of the engine is required and unfortunately proper equipment for this operation is rarely available at the scene of submersion. This brings in the element of time; therefore means must be taken to prevent corrosion, insofar as possible, until the time when the engine is completely dismantled and each part cleaned. As brought out previously the action of the air creates the corrosion, therefore all parts of the engine should be coated as thoroughly as possible with oil to prevent the air reaching them. It is so important that the air be kept from contacting the wet steel parts that in a case where oil is not available it is often-times better to allow the engine to remain under water until some slushing medium is obtained providing, of course, that this can be done within a reasonable length of time.

Too much stress cannot be given to the importance of working quickly if it is expected that the engine is to be salvaged. Therefore, arrangements must be promptly made to dismantle the engine as quickly as possible and thoroughly clean and slush each part. If the submersion occurred in salt water it is recommended that as soon as the engine is dismantled all parts other than electrical equipment be washed in hot, fresh water, dried and slushed with lubricating oil that has been heated to 180 deg. F. (82 deg. C.). Electrical equipment such as starters and generators should be thoroughly flushed with fresh water, dried, and overhauled before using. When accessories are being overhauled, they should be visually checked for detrimental corrosion, the condition of all insulation determined and all electrical circuits thoroughly tested before reassembly. All windings that are otherwise serviceable should be baked in an oven at 140 deg. F. (60 deg. C.), for four hours before reassembly. Ignition wire manifold rings may be salvaged, but all flexible conduit and ignition wire must be replaced. Replace magnetos that have been submerged in either fresh or salt water.

A careful inspection must be made of each part salvaged to ascertain not only the extent of damage caused by corrosion but also for other defects caused by the sudden cooling action of the water in cases where the engine was at operating temperature at the instant prior to submersion. In cases where the engine has been submerged in salt water for any length of time, it is reasonable to expect that parts made of aluminum and particularly those made of magnesium will have been destroyed.

# SECTION 1

## SHOP MATERIALS

**CLEANING SOLUTIONS** A suitable solution for use in an open-type tank to remove heavy coatings of paint, enamel, etcetera, from engine parts may be made up as follows: Add four to seven parts water to one part of No. 70 Gerlach Stripper, if available, or Gunk. Heat the solution and maintain a temperature of 80-100 deg. F. while the parts are immersed.

A suitable solution for use in a pressure-type tank to remove heavy coatings not softened by the No. 70 Gerlach or Gunk solution may be made up as follows: Add four parts of water to one part of No. 99 Gerlach Cleaner. A pressure type tank is required with this cleaner in order to obtain the desired temperature of 260-280 deg. F. which is necessary to make this cleaner effective.

Gerlach No. 70 Stripper, and No. 99 Cleaner, may be obtained from Gerlach Co., 3567-71 Sepviva Street, Philadelphia, Penn.

Gunk may be obtained from Curran Corp., Malden, Massachusetts.

**CLEANING GASOLINE** Gasoline used for cleaning and washing engine parts should be a good grade of ordinary motor gasoline to which no detonation inhibitors or coloring matter has been added.

**COTTER PINS** Cotter pins used in the assembly of Wright engines should meet the following specifications:

| Pin Diameter | Vickers Hardness | Rockwell Hardness 15N |
|---|---|---|
| 1/16 inch and less | 190-300 | 60-75 |
| 3/32 inch | 165-235 | 53-67 |
| 1/8 inch and over | 140-200 | 50-65 |

One prong of the pin must be capable of being bent 180 deg. on itself without showing any signs of rupture or cracking and the flat side of the prong should form the outside of the bend.

**CUTTING OILS** To provide for the proper lubrication and cooling of the various machining tools used during the repair of engine parts and to insure obtaining the desired surface finishes, the following type coolants are recommended:

STEEL

Rough Turning—1 part soluble oil, 12 parts water
Tapping —Sulphurized chlorinated cutting oil
Threading —Sulphurized cutting oil
Drilling —Sulphurized cutting oil
Reaming —Sulphurized cutting oil
Boring —Sulphurized cutting oil

ALUMINUM

Cutting —24 parts kerosene, 1 part sulphurized cutting oil
Tapping —1 part sulphurized cutting oil, 24 parts mineral seal oil
Threading —1 part sulphurized cutting oil, 24 parts mineral seal oil
Drilling —1 part sulphurized cutting oil, 24 parts oil or kerosene
Reaming —1 part sulphurized cutting oil, 24 parts oil or kerosene
Boring —1 part sulphurized cutting oil, 24 parts oil or kerosene

BRONZE

Tapping —Sulphurized cutting oil (low active sulphur)

All other machining of bronze may be done with 1 part soluble oil and 24 parts water.

NOTE: Sulphurized cutting oils as recommended here may be purchased ready to use or in a base form. If purchased in base form, a suitable cutting oil may be blended with 28 per cent paraffin oil, 100 viscosity at 110 deg. F. Increase or decrease the amount of base used in proportion to the difficulty experienced in machining the material.

Sulphurized cutting oil may be obtained from Quaker Chemical Products Corp., Conshohocken, Pennsylvania; sulphurized chlorinated oil from Stuart Oil Co., Chicago, Ill.; and soluble and mineral seal oil from any major oil company.

**DRY ICE BATH** Either alcohol or gasoline may be used as the liquid in the preparation of a chilling bath. One gallon or less is usually sufficient to accommodate parts such as valve guides or seats. Break the dry ice with a hammer into 1 inch or 1½ inch cubes and add about five cubes to the liquid. This is sufficient to lower the temperature to the desired point and it then can be maintained by adding one or two cubes at a time. If the container is insulated with ground cork or sawdust, lower temperatures can be obtained.

If dry ice is not available, small parts such as bushings, valve seats, valve guides or other similar parts may be chilled by placing in a freezing compartment of a mechanical refrigerator. Small parts may also be chilled to the desired temperature by placing the part in a receptacle which has been packed in cracked ice and rock salt. Fill the receptacle with enough alcohol to cover the part completely when the desired temperature has been obtained, allow the part to remain in the solution for the recommended time period. To prevent corrosion, do not allow the salt solution to contact the parts and do not handle steel parts after preparing the salt solution until the hands have been washed thoroughly.

**EMERY AND CROCUS CLOTH** No. 320 emery cloth may be obtained in either rolls or sheets. The rolls may be obtained from Carborundum Co., Niagara Falls, N. Y., and the sheets from Behr Manning Co., Troy, N. Y. No. 120 sheet emery cloth may be used, and may be obtained from Carborundum Co., Niagara Falls, N. Y.

Crocus cloth may also be used in sheets or rolls and may be obtained from Behr Manning Co., Troy, N. Y.

**ETCHING FLUID FOR MARKING PARTS** Zincograph used as a means of identifying parts may be procured from Langbein Co., Brooklyn, N. Y. This fluid is used to saturate a stamp pad and a rubber stamp used to apply the mark. After a part is marked, the surface should be immediately coated with engine oil to prevent corrosion. Zincograph may be procured in either blue (No. 1) or green (No. 2) color.

Durable rubber stamps may be procured from Sheridan and Nichol Inc., 64 Murray St., New York, N. Y.

**FIBER** Hard fiber rods have a variety of uses in the shop. Rods approximately 5 inches in length by ¾ inch and 1 inch in diameter will be found to be the most convenient sizes, and may be obtained from Diamond Fiber Co., Wilmington, Delaware.

**GASKET PASTE** Where it is desired to use a gasket paste on a gasket or parting surface, either Blue Rock Gasket Paste, obtainable from the Radiator Specialty Co., Charlotte, North Carolina, or Titeseal, obtainable from the Fostoria Steel Corp., Fostoria, Ohio, may be used on the gaskets; and Permatex obtainable from Permatex Co., Long Island City, New York, may be used on the parting surfaces or crankcases.

**GRINDING WHEELS** It is recommended that a No. G-90-PW carborundum wheel be used for grinding nitrided cylinder barrels. The size of the grinding wheel is a function of the spindle speed of the grinding machine used. Information on sizes of wheels will be supplied by the engine manufacturer. These grinding wheels may be procured from the Carborundum Co., Niagara Falls, New York.

**GRINDING LUBRICANT AND COOLANT** A suitable grinding lubricant can be made up as follows: To 50 gallons of water add 5 pounds Economy Grinding Lubricant. Economy Grinding Lubricant may be procured from White and Bagley, Worcester, Massachusetts.

An alternate lubricant and coolant can be made up by mixing 1 gallon International Compound No. 137 with 75 gallons of water. International Compound No. 137 may be procured from the International Chemical Company, Philadelphia, Pennsylvania.

**HONING STONES** For honing nitrided cylinder barrels, a No. B-500MHE-6 stone is recommended. These stones may be procured from the Carborundum Co., Niagara Falls, New York.

For honing the steel surfaces of the knuckle pin holes in the master rod a No. 400 stone is recommended. These stones may be procured from the Norton Co., Worcester, Massachusetts.

For honing the chromium-plated surfaces of knuckle pin holes, a No. DU400 stone is recommended. These stones may be procured from the Carborundum Co., Niagara Falls, New York.

**HONING LUBRICANT** A suitable honing lubricant can be made up as follows: 75 parts kerosene oil to 15 parts International 155-D-S compounded by volume. International 155-D-S compound may be procured from the International Chemical Co., Philadelphia, Pennsylvania.

**HOT OIL BATH** Two electrically-heated oil baths which incorporate thermostatic controls are recommended for use in heating the various engine parts where needed to obtain certain required shrink fits. This type of bath is desirable for the reason that temperature can be controlled within desired limits more conveniently.

Two baths are recommended, one for the high oil temperature and the second for lower oil temperature so that two parts requiring different temperatures may be heated simultaneously.

**LAPPING COMPOUNDS** 3M oil mixed Lapping Compound grade 500-2A or equivalent is recommended for lapping valves or for use on a lapping plate. This compound may be procured from the Minnesota Mining and Manufacturing Co., Minneapolis, Minnesota. This product may be obtained in ¼, ½, 1 and 5 pound cans.

**LUBRICATING OIL** It is recommended that Grade 120, Spec. No. 5817C engine lubricating oil be used in the testing of C9GC engines. Should testing conditions warrant the use of a lighter or heavier grade of oil, the recommendations of the engine manufacturer must be obtained.

Any engine lubricating oil which meets the requirements of Spec. 5817C may be used in all C9GC engines. The following oils have been approved under Spec. No. 5817C and are listed alphabetically:

DOMESTIC

Aero Life 120X, Union Oil Co. of California
Aero Mobiloil Green Band 7612, Socony Vacuum Oil Co. Inc. and Associated Companies
Aero Shell 120, Shell Oil Co. Inc.
Castrolaero WW, C.C. Wakefield & Co. Ltd.
Esso Aviation Oil 120, Standard Oil Co. of N. J. and Affiliates
Gulf Airline 60, Gulf Refining Co.
Gulf Airfleet Oil 60, Gulf Refining Co.
Penola Aviation Oil 120, Penola, Inc.
Pennzoil Aircraft XX-WA Spec. 12820, The Pennzoil Co.
RPM Aviation Oil, Standard Oil Co. of California
RPM Aviation Oil, Special, Standard Oil Co. of California
Sinclair Pennsylvania 120-GQ, Sinclair Refining Co.
Sinclair Pennsylvania 120-GR, Sinclair Refining Co.
Sinclair Pennsylvania 120-GS, Sinclair Refining Co.
Sinclair Pennsylvania 120-GX, Sinclair Refining Co.
Standard Aviation Oil 120, Standard Oil Co. of California
Texaco Aircraft Engine Oil 120G, The Texas Co.
Tiolene AA, Pure Oil Co.
Ty-Penn Aviation 120-A, Tide Water Associated Oil Co.
Veedol Aviation Oil 120A, Tide Water Associated Oil Co.
Wolf's Head 8-120, Wolf's Head Oil Refining Co.

FOREIGN

Aero Life, 120X, Union Oil Co. of California
Aero Shell 120A, Shell Oil Co.
Aero Shell 120X, Shell Oil Co.

Aero Shell Heavy X, Shell Oil Co.
Castrolaero WW, C. C. Wakefield & Co. Ltd.
Intava Green Band (IAA-748), Intava, Ltd.
RPM Aviation Oil Special, Standard Oil Co. of California
Sinclair Pennsylvania 120-GQ, Sinclair Refining Co.
Sinclair Pennsylvania 120-GR, Sinclair Refining Co.
Sinclair Pennsylvania 120-GS, Sinclair Refining Co.
Standard Aviation Oil 120, Standard Oil Co. of California
Stratosoil Type 120, Sadonia Limited
Ty-Penn Aviation 120-A, Tide Water Associated Oil Co.
Veedol Aviation Oil 120-A, Tide Water Associated Oil Co.

As further tests are conducted, additional oils may be approved and added to the list, or as test may decide, some of these now listed may be removed. Pending the approval of other oil, however, only those listed above should be used in the C9GC engine. For final confirmation concerning any oil, communicate with the engine manufacturer.

Specification No. 5817C covers the grade of engine lubricating oil designated as Grade 120. This specification is as follows:

(1) Only refined petroleum oils without mixtures of fatty oils, resins, soaps or other compounds will be accepted unless otherwise specified.

(2) The oil shall be free from water, dirt or chips and shall not attack or corrode bearing materials, aluminum, magnesium, steel or copper alloys.

(3) The following are the requirements:

| | |
|---|---|
| Viscosity at 210 deg. F. | 115-125 |
| Viscosity Ratio 100 deg. F. | 14.5 |
| Pour Point deg. F. max. | †20 |
| Flash Point deg. F. min. | 490 |
| Fire Point, deg. F. min. | 590 |
| Carbon Residue max. per cent | 1.00 |
| Ash Maximum per cent | None |
| Neutralization No. max. | .10 |
| Precipitation | None |
| Evaporation Loss Maximum per cent | .50 |
| Sulphur (Bomb Method) max. | .50 |

The viscosity at 100 deg. F. shall not be more than the value obtained by multiplying the viscosity at 210 deg. F. by the viscosity ratio.

The oil shall separate completely in one hour from an emulsion with distilled water at 180 deg. F.

New types of oil or new manufacturers shall be approved by the engine manufacturer only after a full scale engine test has been made in accordance with the engine manufacturer's standard practice for engine testing of lubricating oil. After approval of a new oil, results of laboratory tests in shipments shall be identical with the approved sample within the accuracy prescribed by ASTM for the test in question.

The use of oils which do not meet these specifications constitutes misuse of the engine and voids the engine warranty. The engine manufacturer will not be responsible for any damage which may result from the use of oils which do not meet these specifications. The engine manufacturer will be the sole judge as to whether or not the damage resulted from the use of such oils.

**MAGNETIC TYPE INSPECTION SOLUTION** When magnetized parts are to be dipped in a bath of magnetic powder solution, the solution is made of 1 gallon Stoddard Solvent (Varsol or Ultrasene) and 1 ounce of black magnetic rouge. Magnetic rouge may be obtained from Binney & Smith Co., 41 East 42nd Street, New York, N. Y. Varsol is manufactured by the Standard Oil Co. and Ultrasene by the Atlantic Refining Co.

**ENAMELS** T27B Zinc Chromate, 225 black enamel, 5855 black enamel, and 5860 blue grey enamel are obtainable from Pratt and Lambert, Long Island, New York.

Sovasol No. 74 obtainable from Socony Vacuum, and Amsco B, obtainable from American Mineral Spirits Co., 155 E. 44th Street, New York, N. Y., are used for thinning the priming and finishing coats.

**GRITBLAST MATERIALS** Flint Shot Jr. (No. 30 mesh) or Blastite Carborundum No. 30 is suitable for sandblasting external parts. Alundum No. 90 or any non-

metallic gritblast material may be used for the inside of piston and cylinder heads and valves.

Flint Shot Jr. may be obtained from Whitehead Bros. Co., Buffalo, New York. Blastite Carborundum No. 30 may be obtained from the Carborundum Co., Niagara Falls, New York. Alundum No. 90 may be obtained from Norton Co., Worcester, Massachusetts.

**LOCK WIRE** Stainless steel wire used for locking the various internal and external parts of the engine is available in two sizes. No. 17 (B. & S. Gage) .044 inch diameter is used for external lockwiring. No. 20 (B. & S. Gage) .031 inch diameter is used for internal lockwiring.

Stainless steel wire may be purchased from the Metal Alloy Wire Co. Inc., Moore, Pennsylvania, and should be procured in accordance with AMS Specification No. 5685A.

Wire gages may be procured from Brown and Sharp, Providence, Rhode Island.

**THREAD COMPOUNDS** Glyptal may be used as a thread-sealing medium and may be obtained from the General Electric Co., Niagara Falls, New York.

A good thread lubricant that may be used for driving studs in conjunction with Glyptal is a compound AN3080 which may be obtained from E. F. Houghton Co., Philadelphia, Pennsylvania.

**ENGINE SLUSHING COMPOUNDS** Do not use external slushing compound on internal parts or internal slushing compound on external parts. Use new slushing compound and dehydrators for each engine being slushed.

The internal slushing compound, AMS3072, can be obtained from the Standard Oil Co. of New Jersey, 26 Broadway, New York, N. Y.

The external preservative compound, Specification AN-C-52, can be obtained from American Oil and Supply of New Jersey, 238 Wilson Stret, Newark, New Jersey.

The light lubricating oil, AMS 3070, used in slushing the carburetor can be obtained from the Standard Oil Co. of New Jersey, 26 Broadway, New York, N. Y.

The Wells Roller Thermosealer used to seal the pliofilm bags can be obtained from Wells Mfg. Corp., San Francisco, California.

The Protek-Sorb (Silica-Gel) and the humidity indicator can be obtained from the Davison Chemical Corp., Baltimore, Maryland.

The cylinder dehydrators, plug protectors, and cable attachments can be obtained from Chandler Evans Corp., South Meridan, Connecticut. The pliofilm envelopes can be obtained from Kennedy Car Liner and Bag Co., Shelbyville, Indiana, or the Shellmar Products Co., 350 Fifth Avenue, New York, N. Y.

**STONES** The following stones are recommended for use during the various recommended hand stoning operations:

(1) Arkansas Oil Stones—1 in. x 1 in. x 6 in.—polishing crankshafts, obtainable from Behr Manning, Troy, New York.

(2) Carborundum Stones—F-41, M-41, 1 in. x 1 in. x 6 in.—pistons—obtainable from Carborundum Co., Niagara Falls, New York.

(3) Norton stones—320-J, ⅜ in. x ½ in. x 6 in.—cams—obtainable from Norton Co., Worcester, Massachusetts.

(4) Carborundum Stones 220-I, ⅜ in. x ½ in. x 6 in.—cams—obtainable from Carborundum Co., Niagara Falls, New York.

(5) Norton Stones 80-P, ⅜ in. x 4 in.—inside diameters, obtainable from Norton Co., Worcester, Massachusetts.

(6) Medium India Triangular, MT-134, breaking sharp edges on spiral gears, obtainable from Norton Co., Worcester, Massachusetts.

**GASOLINE USED FOR ENGINE TESTING** The gasoline used for the testing of C9GC engines must in all instances conform with the specifications of the gasoline recommended for use in the various models in regular operation.

The engine manufacturer will not be responsible for damage to an engine when any but the specified grade of gasoline is used. The use of gasoline which does not meet the required specifications constitutes misuse of the engine and voids the engine warranty.

**FUEL SPECIFICATIONS** Only gasoline consisting of a blend of refined hydrocarbons derived from crude petroleum and/or natural gasoline will be considered. Dilution with other substances is permitted only as specified herein.

Benzol and similar hydrocarbons may be added in such quantity that the blend meets all requirements for the finished fuel.

The gasoline shall be free from water and suspended matter.

The antiknock value shall be equal to that of a mixture of iso-octane and normal heptane, the proportions by volume being as follows:

| Specification | Iso-Octane | Normal Heptane |
|---|---|---|
| No. 5800 | 65 | 35 |
| No. 5801 | 73 | 27 |
| No. 5802 | 80 | 20 |

The antiknock value shall be determined by direct comparison between a sample of the fuel and specified primary standard octane heptane-mixture, or a secondary standard proved equal to the primary standard in antiknock value under the specified conditions of test.

The antiknock value shall be determined by test in a CFR engine by the CFR Method of Test for knock characteristics of aviation fuels, 1940.

The color of the gasoline shall not be darker than 21 Saybolt before addition of any dye. If toxic detonation inhibitors have been added, the color shall be light blue.

**RUST PREVENTIVE COMPOUND** Anti Corrosion Compound, AMS 3075, may be used as a rust preventive on bearings which are to be wrapped and stored before use. This compound may be procured from the Standard Oil Co. of New Jersey, 26 Broadway, New York, N. Y.

**WRAPPING PAPER** Induwrap, moisture-proof wrapping paper, WAC Specification No. 5530 and 5531, may be obtained from Angier Corp., Framington, Massachusetts.

**SPARK PLUG INSERT COMPOUND** When installing spark plug inserts, Heldite is used, and may be obtained from Hughs Glue Co., Wolfs Head Wharf, England.

**PLATING SOLUTIONS** The solution used for lead plating is Normal Fluoborate Solution and may be procured from Industrial Emulsions Inc., Passaic, New Jersey.

The cleaning solution that is used prior to lead plating bearings and bushings is Clepo No. 64 and may be obtained from Frederic Gumm Chemical Co., Kearney, New Jersey.

# SECTION 2

# SERVICE STATION MANAGEMENT FORMS

Use of the following forms will be found to be of great assistance in the management of a service station. It is essential that a certain amount of paper work be carried out if repairs are to be handled in an efficient manner. The following forms, in addition to the inspection and test forms, comprise the complete story of the engine maintenance and provide a service station with information invaluable not only to the shop personnel but also for dealing with customers.

# ENGINE RECEIVING INSPECTION REPORT

Owner ..... Address ..... Date .....
Total Time ..... Since Overhaul ..... Work Order No. .....
Engine Model ..... Type ..... W.A.C. Engine No. ..... Operator's No. .....
Airplane Make ..... Model ..... No. ..... N. C. .....
Max. Take Off. .H.P. at. .R.P.M. at. .Max. Man. Pres. .Alt. Rate. .H.P. at. .R.P.M. at. .Max. Man. Pres.
Sea Level Rate. .H.P. at. .R.P.M. at. .Max. Man. Pres. .A.T.C. Rate. .H.P. at. .R.P.M. at. .Max. Man. Pres.
Fuel Spec. .... Octane .... Master Rods in .... Cyls.
Oil Spec. .... Temp. .... Pres. .... to .... lbs.
Imp. Gear Ratio ..... Imp. Diameter .....
Compression Ratio .... Reduction Gear Ratio ....
Spark Adv. Degree ..... Frt. ..... Rear. ..
Valve Timing .....

Supercharger Warning Plate Marking:
Use ..... Octane Fuel. Limit Man. Pres. to ..... Inches-Centimeters. Mercury at Sea Level.
Set Prop. to ..... R.P.M. Full Throttle at ..... Feet Altitude.

## EQUIPMENT RECEIVED WITH ENGINE

| Attached | Detached | Description |
|---|---|---|
| | | Accessory Drive Assembly ..... Type Dual ..... |
| | | Carburetor—Make ..... Model ..... Serial No. ..... |
| | | Carburetor Air Screen |
| | | Carburetor Adapter |
| | | Cover Plate Nuts, Spacers, Washers, Etc. |
| | | Cylinder Air Deflectors and Clamps |
| | | Cylinder Head Air Deflectors |
| | | Propeller Shaft Protecting Cap |
| | | Exhaust Gaskets and Palnuts |
| | | Exhaust Manifold |
| | | Fuel Pump—Make ..... Model ..... Serial No. ..... |
| | | Fuel Pump Drive Cover Plate |
| | | Gun Synchronizer Cover Plates |
| | | Generator—Make ..... Model ..... Serial No. ..... |
| | | Generator Drive Cover Plate |
| | | Magneto—R.H.—Model ..... Serial No. ..... |
| | | Magneto—L.H.—Model ..... Serial No. ..... |
| | | Log Book—Sheet |
| | | Oil Drain Tube Assembly |
| | | Oil Filter |
| | | Priming Elbows |
| | | Priming Lines |
| | | Propeller Attaching Parts |
| | | Propeller Governor Attaching Parts |
| | | Spark Plugs—Make ..... Type ..... |
| | | Starter—Make ..... Model ..... Serial No. ..... |
| | | Starter Drive Cover Plate |
| | | Supercharger Regulator Assembly No. ..... |
| | | Thermocouple—Cylinder Base |
| | | Thermocouple ..... Spark Plug ..... Cyl. No. ..... |
| | | Vacuum Pump—Make ..... Model ..... Serial No. ..... |
| | | Vacuum Pump Drive Cover Plate |
| | | Wiring Harness—Type ..... Make ..... |

Inspector .....

Engine No. .....

The Receiving Report should be completely filled out by the foreman of the hangar crew if the engine was received in an airplane. If delivered directly to the overhaul shop then this form is filled out by a shop inspector.

The manner of using the form is obvious; however, the following suggestions are offered.

The serial number of the engine and type symbol should be ascertained from the engine nameplate, checked against the engine log book and noted in the proper spaces.

If the operator has assigned a number to the engine, it should be recorded in the space provided. Record the serial numbers of the various accessories.

If the engine was received in an airplane fill in that part of the record. This information will be of assistance to the hangar personnel when re-installing the engine in the airplane.

Indicate all parts that were received with the engine, noting the quantity and whether or not the parts were attached to or detached from the engine.

The absence of a part number before the name of each part indicates that part was not received with the engine.

In the space at the lower part of the form information should be given pertaining to all items such as pipe connections, carburetor throttle arms or cowling braces, with all pertinent information relative to their location and position on the engine. Careful use of this feature of the form will avoid unnecessary labor at the time when the engine is being re-installed in the airplane.

In the same space at the lower part of the form, indicate the external condition of the engine. In this space should be stated such facts as broken or damaged parts, condition of enamel (particularly on the cylinders), oil leaks and general appearance along with any pertinent information supplied by the pilot or operator, such as high or low fuel or oil consumption.

Three copies of the above form should be made out and distributed as follows:

Original—Office File Copy.

Duplicate—Remains with engine while in shop.

Triplicate—Inspector's copy. (When reporting a trouble to the factory it is recommended that a copy of this form be included in the report.)

The ENGINE HISTORY RECORD should be filled out by the man who contacts the engine owner or checks the engine prior to its overhaul. As much information as is available should be taken from the engine log book and entered on the form. It is then filed numerically with other Engine History Record Forms in accordance with the engine serial number. Upon completion of any work on the engine, the information should be entered in the form. The Work Order Number under which the work was performed should always be noted.

| | | | | | |
|---|---|---|---|---|---|
| MODEL | PROP. RATIO | COMP. RATIO | IMPELLER RATIO | CUSTOMERS NO. | SERIAL NO. |
| CARBURETOR— MAKE | TYPE | ASSEMBLY NO. | SETTING NO. | SERIAL NO. | PRESSURE OR GRAVITY FEED |
| MAGNETOS— TYPE | PART NO. R. H. | SERIAL NO. R. H. | PART NO. L. H. | SERIAL NO. L. H. | SPARK ADVANCE-FRT. REAR |
| WIRING HARNESS | THERMO-COUPLE | LEADS | INSTRUMENT | IGNITION SWITCH | SPARK PLUGS |
| OTHER EQUIPMENT- DESCRIPTION. PART NO'S. | | | | FUEL PUMP | PRIMING SYSTEM |
| | | | | SUPERCHARGER PRESSURE GAGE | EXHAUST GAS ANALYZER |
| | | | | ACCESSORY DRIVE ASSY. | ENGINE SPEC. |

| SHIPPED To | ADDRESS | DATE | ORDER No. |
|---|---|---|---|

| | OWNER RECORD | ADDRESS | AIRPLANE MAKE | REFERENCE |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

## COMPONENT PARTS AND ASSEMBLIES IN THIS ENGINE

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADAPTER— AIR SCOOP | ADAPTER— CARBURETOR | ADAPTER— GOVERNOR DRIVE | ARM— ROCKER, EXHAUST | ARM— ROCKER, INTAKE | | BEARING— CENTER MAIN | BEARING— FRONT MAIN | BEARING— REAR MAIN | BEARING— THRUST | BOLT— ROCKER ARM | BRACKET— CAM DRIVE GEAR | BRACKET— CAM GEAR OILING | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| CAM ASSEMBLY— FRONT | CAM ASSEMBLY— REAR | COVER— ROCKER BOX | COVER— SUPER. HOUSING | CRANKCASE— FRONT | CRANKCASE— MAIN | CRANKSHAFT | CYLINDER— FRONT | CYLINDER— REAR | | DEFLECTOR— CYLINDER AIR | DEFLECTOR— CYLINDER HEAD AIR | DIFFUSER PLATE | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| ELBOW— HOT SPOT | EXTENSION— CRANKSHAFT | FLANGE— FRONT SECTION | | GEAR— ACCESSORY DRIVE | GEAR— CAM DRIVING, - FRONT | GEAR— CAM DRIVING, - REAR | GEAR AND PINION— CAM, FRONT | GEAR AND PINION— CAM, REAR | GEAR— GENERATOR DRIVE | GEAR— GOVERNOR DRIVE | GEAR— IMPELLER DRIVE | GEAR— MAGNETO | GEAR— MAGNETO DRIVE |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| GEAR— OIL PUMP DRIVE | GEAR— REDUCTION DRIVING | GEAR— STATY. REDUCTION | GEAR— TACH. & FUEL PUMP | | HOUSING— SUPERCHARGER FRONT | HOUSING— SUPERCHARGER REAR | HOUSING— TACH. & FUEL PUMP | | IMPELLER— SUPERCHARGER | | NUT— PROPELLER HUB | NUT— REAR MAIN BEARING | NUT— REDUCT'N DRIV'G GEAR |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | PIN— KNUCKLE | PIN— PISTON | PINION— GOVERNOR DRIVE | PINION— REDUCTION GEAR | PIPE— INTAKE | PISTON COMPLETE | PLATE— CAM RETAINER | PUMP— OIL | PUSH ROD | | RETAINER— IMPELLER SHAFT | RING— PROP. HUB CENT. - FR'T | RING— PROP. HUB CENT. - REAR |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| ROD— ARTICULATED | ROD— MASTER | | SCOOP— AIR | SCREEN— CARBURETOR | SHAFT— CAM GEAR & PINION | SHAFT— GOVERNOR DRIVE GEAR | SHAFT— IMPELLER | SHAFT— MAGNETO DRIVE | SHAFT— OIL PUMP DRIVE | SHAFT— PROPELLER | SHAFT— TACH. & FUEL PUMP DR. | SHAFT— TACH. DRIVE | SHAFT— TACH. & FUEL PUMP GEAR |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| SHAFT & WORM GEAR— GOV. DRIVE | SHIELD— MAGNETO, R. H. | SHIELD— MAGNETO, L. H. | SLINGER— REAR MAIN BR'G. OIL | SLINGER— THRUST BEARING OIL | SPACER— REAR CENT. RING | STRAINER— OIL | SUMP— OIL | | TACHOMETER DRIVE ASSEMBLY | TAPPET— VALVE | TERMINAL— SPARK PLUG | TOOL KIT | TUBE— PROP. SHAFT BREATHER |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

| | VALVE— EXHAUST | VALVE— INTAKE | VALVE— ROCKER LUBRICATION | VALVE— SUPERCHARGER DRAIN | | | | | | | | | |
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## SERVICE CONTACT—PARTS REPLACEMENTS—ENGINEERING CHANGES—ETC.

REPORTED ENGINE TIME

| DATE | REFERENCE | REMARKS (BRIEF) | DATE | REFERENCE | REMARKS (BRIEF) | DATE | REFERENCE | HOURS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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## PARTS RETURNED FROM THIS ENGINE

| DATE | R.N.NO. | BRIEF DESCRIPTION | DATE | R.N.NO. | BRIEF DESCRIPTION | DATE | R.N.NO. | BRIEF DESCRIPTION | DATE | R.N.NO. | BRIEF DESCRIPTION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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## ENGINE OWNER RECORD

OWNER .....

ADDRESS .....

ADDRESS .....

ADDRESS .....

AIRPLANE .....

ENGINE SERIAL NUMBER .....

ENGINE MODEL .....

A complete alphabetical index of engine owners is required to provide a means of customer contact and as a cross index to the ENGINE HISTORY RECORDS.

## SERVICE WORK ORDER

## SHOP COPY

Work Order No. .....

Supplement .....

Received From ..... Date .....

Address ..... Customer's Order No. .....

Charge ..... Terms .....

Address ..... F. O. B. .....

Date Received ..... Via ..... Transportation Charges ..... M. O. No. ..... R. N. .....

| | Item No. | Quan. | Part No. | Part Name | Engine No. | Total Time | Part Time | Customer's Reports |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

Instructions to Department—

Date Promised | Inspection. Report | Shipment | Approved

When the Work Authorized Above Has Been Accomplished, Date and Sign This Copy and Forward to Billing Dept. | Date | Signed

All work performed in the overhaul shop should be authorized by SERVICE WORK ORDERS. The order should state definitely just what work is to be done or the disposition to be made of the part or parts received. The office copy of these orders should bear the signature of the customer authorizing the work or a reference as to the nature of the authority for procedure.

If definite advice or instructions cannot be given when the original order is issued or if there are any subsequent changes in the instructions, the same form should be used in the issuing of supplements to the original order using the original order number and identifying the supplements by letters, a, b, c, etcetera. Upon completion of the work called for, the shop copy should be signed by the shop foreman as completed and then used as a reference for billing.

It is advisable to have the shop copy made of heavy stock for durability and if it is desired this copy can be made smaller by eliminating the lower half of the form which is primarily for office use.

## PARTS REQUISITION

Date .....

Work Order No. .....

..... STORES Engine No. .....

| Item | Part Number | Quan. Ordered | Quan. Del'v'd | Back Ordered | Part Name | Stock Location |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |

| Requisitioned By | Approved | Posted | Received |
|---|---|---|---|
| Service Inspector | | | |

Requisitions for parts should be made out either by the inspector whose duty it is to decide whether or not a part should be replaced or by a clerk working with the inspector. As soon as a requisition is made out it should be signed by the foreman and turned in to the stock room, even though the parts are not to be taken out of stock immediately as would be the case if an estimate had to be submitted to the customer, before proceeding with the overhaul. This procedure enables the stock clerk to anticipate requirements and order the required parts, thus avoiding unnecessary delay when the approval is obtained.

## DESCRIPTION OF PART — Drawing Number

| Yearly Sales | 19 | 19 | 19 | 19 | 19 | 19 | 19 | Maximum | Minimum | Stock Room Location / Cost | Selling Price |
|---|---|---|---|---|---|---|---|---|---|---|---|
| First Half | | | | | | | | | | | |
| Second Half | | | | | | | | | | | |

Number of Parts Used per Engine for Each Model

| Model | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number of Parts Used | | | | | | | |

Remarks:

| Date | Order Number Factory | Order Number Dealer | Ordered | Received | Sold | Balance On Hand | Date | Order Number Factory | Order Number Dealer | Ordered | Received | Sold | Balance On Hand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
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PERPETUAL INVENTORY CARDS are kept by the stock clerk and filed numerically according to the part number. Their indication of the proper maximum quantities is a great help in ordering.

## PURCHASE REQUISITION

To ..... Date .....

| Ship Via | F. O. B. | Date Ordered | Terms | Purchase Order |
|---|---|---|---|---|
| | | | | |

Inspection ..... Work Order No. ..... Contract No. .....

| Part No. | Description | Price |
|---|---|---|
| | | |
| | | Requirements Quantity / Date |
| | | |
| | | |
| | | |

Chemical - Physical - Test Piece — Quotation

Issued By
Dept. ..... Deliver To ..... Charge .....

Used For

| Model | Usage | | Requirements In Detail Quantity | Sales Order | Contract |
|---|---|---|---|---|---|
| | Reg. | | | | |
| | Stock | | | | |
| Units Per Eng. | To Be Pur. | | | | |
| | Approved Dept. Hd. | Approved Pur. Agent | | | |
| Issued By | | | | | |

PURCHASE REQUISITIONS may be used by the shop foreman or stock clerk, to request the issuance of a purchase order.

## SHIPPING ORDER

Date .....

Ship To .....

Address .....

City and State .....

Ship Via ..... F. O. B. .....

W.A.C. Order No. ..... Supp. B. O. ..... Customer's Order No. .....

Shipping Marks

Made In U. S. A.

Charge To ..... Terms .....

Address ..... Ship From .....

| Item No. | Quantity Ordered | Quantity Shipped | Part No. | Description | Unit Price | Total |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |

Reference ..... Engine No. ..... Model ..... Code .....

OWNER

Material Issued ..... Box No. .....

Inspected By ..... Net Weight .....

..... Tare .....

Packed By ..... Gross Weight .....

..... Size .....

Date Shipped .....

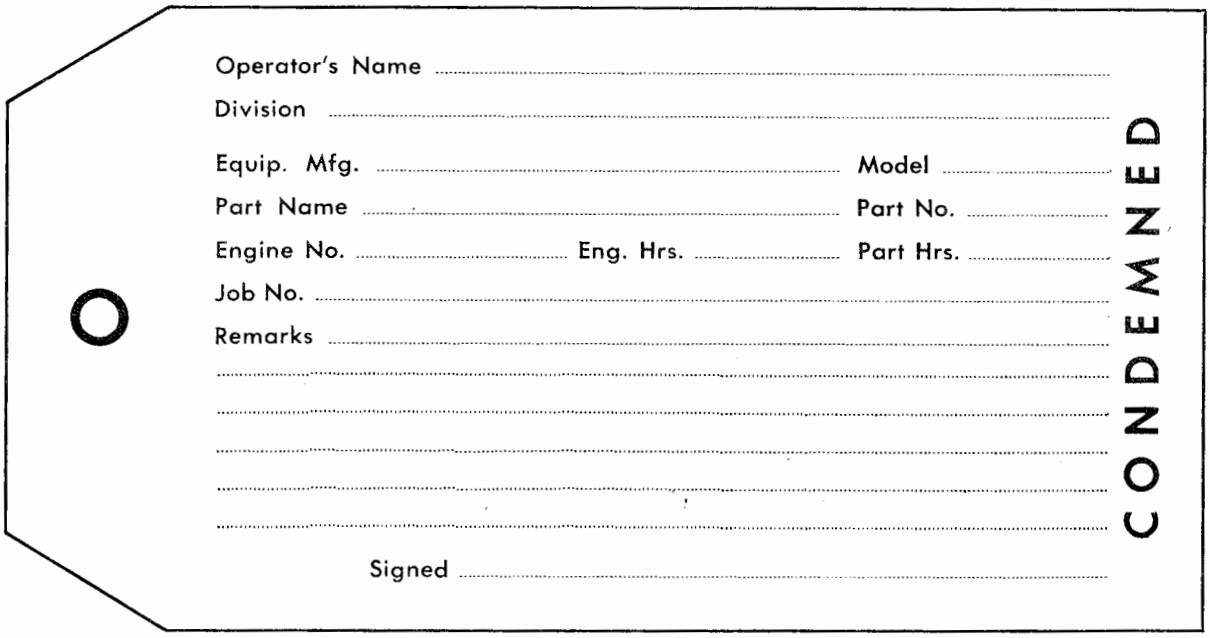
Via .....

Charges .....

Shipped By .....

To eliminate the necessity of giving verbal instructions, this shipping order is prepared when notification is received that a shipment or delivery of customer's material is ready to go forward. All parts to be shipped and all other pertinent information required is filled in and the original is filed with all other papers pertaining to the transaction. A copy is mailed or delivered to the customer as notice that shipment has gone forward. A copy should be packed with the shipment. When shipment is made the original should be marked with the shipping date.

## CONDEMNED PART TAG




CONDEMNED PART TAGS are filled out by the inspector and attached to the part as soon as it is decided that the part is unfit for further use. They should be printed on red stock.

## RETURN NOTICE

To: Wright Aeronautical Corporation,
Paterson, New Jersey.
Attention:—Service Division.

Date .....

Reference .....
(Customer's Shipping Order Number)

The material listed below has been shipped to you this date

Via ..... (Transportation Charges must be prepaid on ALL return shipments.)

For [ ] Repair—See Purchase Order No. ..... Attached.
[ ] Replacement—See Purchase Order No. ..... Attached.
[ ] Adjustment or Credit.

(Parts returned for repair or replacement should NOT be included on the same Return Notice with parts returned for Adjustment or Credit.)

| Item No. | Quan. | Part No. | Part Name (Abbreviate) | Engine No. | Total Engine Time | Time On Part | Explanation (Reason for Return) | Customer's Reference | Leave Blank |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Original — This copy to be mailed to Wright Aeronautical Corporation.

IMPORTANT
Any parts covered by a Return Notice which constitutes a claim for adjustment will be scrapped in the event that the claim is disallowed unless specific request is made on the face of this form to return such parts.

Shipped by .....

Address .....

.....

(For Factory Use Only)

S. D. O. No.

M. O. No.

(This number must appear on ALL correspondence in reference to this shipment.) R. N.

RETURN NOTICES are used when parts are returned to the factory for repair, adjustment or inspection and credit. Four copies of this form are filled out and distributed as follows:

Original—Mailed to factory.
Duplicate—Retained by consignor.
Triplicate—Sent with shipment.
Quadruplicate—Mailed to the factory.

# SECTION 3

# INSPECTION FORMS

Inspection forms similar to those given in this chapter, should be used by the inspector to record the condition and recommendations for the repair of each part of the engine. One column is provided for listing the part numbers of the various parts. This is particularly useful as a means of identifying each part in cases where a factory change which incorporated a change in part number was made. Copies of the forms should accompany the various parts assemblies, for the guidance of the mechanics who are to perform the repair operations.

It is desirable that all the inspection forms be completely filled out so that a true record can be kept of the condition of each engine as received. Inspection forms should be used as a guide when making out requisitions for new parts that will be required during the overhaul of the engine. Parts are listed in the inspection forms under the assemblies of which they are a part, and in the same order in which they are covered in the chapter entitled "Inspection."

It is frequently the case that some defect or unusual condition of a part will not have been detected during inspection but will be found when the part is being repaired. In such a case, the part and the inspection form should be returned to the inspector so that he may record its true condition.

The inspector should file the original copy of the inspection form so that reference can be made to it at time of the next overhaul. Such reference affords a check on the amount of wear and general performance of the engine during length of service between overhauls.

# ENGINE INSPECTION REPORT

Page No. 1 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | 1 | C.C. FRONT SECTION | | |
| | | Finished Surfaces | OK | |
| | | Studs | OK | |
| | | Oil Passages | OK | |
| | | Thrust Bearing Retainer I.D. | — | |
| | | Governor Drive Gear Shaft Bushing | | |
| | | Frt. Sec. Mn. Sec. Attach. Cap-screws | OK | |
| | | Front Section Spacer | OK | |
| | | Front Section Flange | OK | |
| | 2 | PROPELLER GOVERNOR DRIVE | | |
| | | Governor Drive Gear | OK | |
| | | Governor Drive Gear Shaft | OK | |
| | | Attaching Screws | MISSING (1) | |
| | | Governor Drive Subst. Cover | — | |
| | 3 | VALVE TAPPETS | | |
| | | Socket | OK | |
| | | Spring | OK | |
| | | Roller | OK | |
| | | Bushing | OK | |
| | | Pin | OK | |
| | 4 | VALVE TAPPET GUIDES | | |
| | | Oil Holes | OK | |
| | | Flange | OK | |
| | 5 | PROPELLER SHAFT | | |
| | | Reduction Gear Ratio | OK | |
| | | Threads | OK | |
| | | Splines | OK | |
| | | Journals | N-D-A | |
| | | Thrust Bearing Journal O.D. | — | |
| | | Oil Passages | OK | |
| | | Front Bushing | OK | |
| | | Rear Bushing | OK | |
| | | Sleeve | OK | |
| | | Thrust Bearing Spacer | N-D-A | |
| | | Pinion Bushings (.666) | N-D-A | |
| | | Thrust Nut | OK | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 2 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | **THRUST BEARING** | | |
| | | Balls | ~~OK~~ N-D-S | 6 |
| | | Outer Race ..... O.D. | — | |
| | | Inner Race ..... I.D. | — | |
| | | Retainer | OK | |
| | | Axial Looseness | OK | |
| | | **STATIONARY RED. GEAR SUPPORT** | | |
| | | (.5625) | — | |
| | | Mounting Flange | — | |
| | | Sleeve | — | |
| | | Oil Passages | — | |
| | | **STATIONARY RED. GEAR (.5625)** | | |
| | | Teeth | — | |
| | | Capscrew Holes | — | |
| | | Capscrews | — | |
| | | **STATIONARY RED. GEAR (.666)** | | |
| | | Mounting Flange | OK | 7 |
| | | Inside Diameter | — | |
| | | Oil Passages | OK | |
| | | Teeth | N-D-A | |
| | | Bolts | OK | |
| | | Nuts | OK | |
| | | **PINIONS** | | |
| | | Oil Passages | OK | 8 |
| | | Teeth | OK | |
| | | Journals | N-D-S | |
| | | Pinion Bushings (.5625) | N-D-S | |
| | | Pinion Bolts | OK | |
| | | Pinion Nuts (.5625) | — | |
| | | Pinion Guard Ring | — | |
| | | Pinion Carrier (.5625) | — | |
| | | Carrier Bolts (.5625) | — | |
| | | Carrier Nuts (.5625) | — | |
| | | **REDUCTION DRIVING GEAR** | | |
| | | Internal Teeth | OK | 9 |
| | | External Teeth | OK | |

Inspected By .....

Approved By .....

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Engine No. .....

# ENGINE INSPECTION REPORT

Page No. 3 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Splines | OK 10 | |
| | | Retaining Nut | OK | |
| | | Lock Screw | OK | |
| | | **TORQUE INDICATOR PARTS** | | |
| | | Torque Arm | — | |
| | | Torque Arm Support | — | |
| | | Balls | — | |
| | | Torque Indicator Valve | — | |
| | | Torque Indicator Housing | — | |
| | | Torque Indicator Housing Cover | — | |
| | | Torque Arm Stop Screw & Lock Nut | — | |
| | | Booster Pump Housing | — | |
| | | Booster Pump Housing Cover | — | |
| | | Booster Pump Gears | — | |
| | | **C.C. MAIN SECTION FRONT HALF** | | |
| | | Finished Surfaces | OK 11 | |
| | | Front Section Attaching Screw Holes | OK | |
| | | Cylinder Hold-Down Capscrew Holes | OK | |
| | | Internal Attaching Lugs | OK | |
| | | Main Section Attaching Bolts | OK | |
| | | Main Section Attaching Nuts | OK | |
| | | Cam Bearing Ring | — | |
| | | Front Main Bearing Ring ..... I.D. ..... | — | |
| | | Reduction Driving Gear Spacer | OK | |
| | | **CAM AND CAM DRIVE** | | |
| | | Cam Lobes | OK 12 | |
| | | Cam Internal Teeth | OK | |
| | | Cam Hub | OK | |
| | | Cam Drive Gear Bracket | — | |
| | | Bracket Attaching Screws | — | |
| | | Cam Drive Gear Bracket Spacer | — | |
| | | Cam Bearing Ring Spacer | — | |
| | | Cam Drive Gear | OK | |
| | | Intermediate DRIVE GEAR | OK | |
| | | Cam Drive Gear Spacer | — | |
| | | Cam Drive Pinion | OK | |
| | | Cam Drive Gear and Pinion Bolt | OK | |
| | | Cam Drive Gear and Pinion Nut | OK | |

Inspected By .....  Approved By .....

.....  Engine No. .....

# ENGINE INSPECTION REPORT

Page No. 4 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | **CRANKCASE MAIN SECTION REAR HALF** | | |
| | | Finished Surfaces | OK 13 | |
| | | Cylinder Hold-Down Capscrew Holes | OK | |
| | | Superch. Frt. Hsg. Attach. Screw Holes | N-D-A | |
| | | Internal Attaching Lugs | OK | |
| | | Rear Main Bearing Ring I.D. | — | |
| | | **SUPERCHARGER FRONT HOUSING** | 14 | |
| | | Finished Surfaces | OK | |
| | | Studs | OK | |
| | | Oil Passages | OK | |
| | | Frt. Hsg. to Mn. Sec. Attach. Capscrews | OK | |
| | | Mounting Lugs | OK | |
| | | Intake Port Threads | OK | |
| | | Intake Pipe Packing Nuts | OK | |
| | | Impeller Shaft Bearing Support | OK | |
| | | Impeller Shaft Bearing Support Ring | OK | |
| | | **SUPERCH. FRT. HSG. BREATHER OR SUBSTITUTE COVER** | | |
| | | Breather Screen | — | |
| | | Breather Relief Valve | — | |
| | | **SUPERCHARGER REAR HOUSING** | | |
| | | Finished Surfaces | OK 15 | |
| | | Studs | OK | |
| | | Oil Passages | OK | |
| | | Fuel Venturi Extension Tube | OK | |
| | | Manifold Pressure Gauge Tube | OK | |
| | | Oil Seal Vent Tube | OK | |
| | | Oil Seal Vent | OK | |
| | | Rear Impeller Shaft Sleeve | OK | |
| | | Impeller Drive Gear Front Bushing | OK | |
| | | **DIFFUSER PLATE** | | |
| | | Vanes | OK 16 | |
| | | Inside Diameter | — | |
| | | Attaching Nuts | OK | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 5 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | **GUN SYNCHRONIZERS** | | |
| | | Lower Housing | — | |
| | | Upper Housing | — | |
| | | Shim | — | |
| | | Plunger | — | |
| | | Cam Follower | — | |
| | | Cam | — | |
| | | Nut | — | |
| | | Attaching Nuts and Capscrews | — | |
| | | **GUN SYNCH. DRIVE SHAFTS** | | |
| | | Teeth | N-A 17 | |
| | | Journals | N-A | |
| | | Plugs | N-A | |
| | | Threads | N-A | |
| | | **GUN SYN. DR. SH. SUPPORTS OR SUBST. COVERS** | | |
| | | Flange | — | |
| | | Bushings | — | |
| | | **FUEL PUMP DRIVE SHAFT** | | |
| | | Teeth | OK | |
| | | Journals | N-D-A 18 | |
| | | Plug | OK | |
| | | Splines | OK | |
| | | **FUEL PUMP DR. SHAFT SUPPORT** | | |
| | | Flange | OK 19 | |
| | | Bushings | OK | |
| | | Oil Seal | OK | |
| | | Fuel Pump Substituting Cover | — | |
| | | **CUNO OIL FILTER** | | |
| | | Filter Cartridge | OK 20 | |
| | | Attaching Nuts | OK | |
| | | Op. of Autom'c Turning Mechanism | OK | |
| | | Operation of Relief Valve | — | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 6 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | **SUPERCHARGER DRAIN VALVE ASSEMBLY** | | |
| | | Plug | OK 21 | |
| | | Valve Housing | OK | |
| | | Disc | N-D-A | |
| | | Valve Body | OK | |
| | | Bushing | N-D-A | |
| | | Venturi Tube | N-D-A | |
| | | **SUPERCHARGER REAR HOUSING COVER** | | |
| | | Finished Surfaces | OK 22 | |
| | | Studs | OK | |
| | | Oil Passages | OK | |
| | | Oil Pressure Gauge Tube | OK | |
| | | Magneto Drive Gear Shaft Bushings | OK | |
| | | Oil Pump Drive Gear Shaft Bushing | OK | |
| | | Dual Acc. Dr. Gear Shaft Bushing | OK | |
| | | Generator Drive Gear Bushing | OK | |
| | | Gun Syn. Dr. Shaft Thrust Bushings | OK | |
| | | Fuel Pump Drive Shaft Thrust Bush. | OK | |
| | | Interm. Imp. Drive Shaft Rear Bush. | OK | |
| | | Starter Substituting Cover | — | |
| | | Generator Substituting Cover | — | |
| | | Oil Vent Connection | OK | |
| | | **ACC. DRIVE AND STARTER SHAFT** | | |
| | | Journals | OK 23 | |
| | | Splines | OK | |
| | | Bore | OK | |
| | | Twist | N-D-A | |
| | | Springs | N-D-A | |
| | | Pins | OK | |
| | | Starter Shaft Bushing | OK | |
| | | Plate | OK | |
| | | Screws | OK | |
| | | Gear | OK | |
| | | Thrust Ring | OK | |
| | | Spacer | OK | |
| | | Starter Dog | OK | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 7 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Sintered Packing | OK 24 | |
| | | Starter Shaft Packing Retainer | | |
| | | **GENERATOR DRIVE GEAR** | | |
| | | Teeth | OK | |
| | | Splines | OK 25 | |
| | | Journal | OK | |
| | | Plug | OK | |
| | | **GENERATOR DRIVE OIL SEAL** | | |
| | | Retainer | OK | |
| | | Collar | OK | |
| | | Sintered Seal | OK 26 | |
| | | Flanged Washer | OK | |
| | | Spring | OK | |
| | | **MAGNETO DRIVE GEAR & SHAFT** | | |
| | | Spur Gear Teeth | OK | |
| | | Attaching Screws | OK | |
| | | Journals | OK | |
| | | Spiral Gear Teeth | OK | |
| | | Splines | OK 27 | |
| | | Plug | OK | |
| | | **MAGNETO DRIVE OIL SEALS** | | |
| | | Retainers | OK | |
| | | Collars | OK | |
| | | Sintered Seals | OK 28 | |
| | | Flanged Washers | OK | |
| | | Springs | | |
| | | **OIL PUMP DRIVE GEAR** | | |
| | | Teeth | OK | |
| | | Splines | OK 29 | |
| | | Journal | OK | |
| | | Plug | | |
| | | **DUAL ACC. DRIVE GEAR & SHAFT** | | |
| | | Spur Gear Teeth | OK | |
| | | Attaching Screws | OK R | |
| | | Journals | OK | |

Inspected By ..... Approved By .....

..... Engine No. .....

# ENGINE INSPECTION REPORT

Page No. 8 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Spiral Gear Teeth | OK | |
| | | Splines | OK 30 | |
| | | Plug | OK | |
| | | IMPELLER | | |
| | | Hub | OK | |
| | | Blades | OK 31 | |
| | | Splines | | |
| | | IMPELLER SHAFT | | |
| | | Threads | OK | |
| | | Splines | OK 32 | |
| | | Teeth | OK | |
| | | Front Bushing | OK | |
| | | Rear Bushing | OK | |
| | | Front Oil Sleeve | N.G. Ring Missing | |
| | | Rear Oil Sleeve | OK | |
| | | Bronze Washer | OK | |
| | | Steel Washer | OK | |
| | | Thrust Ring | OK | |
| | | Impeller Shaft Retainer | OK | |
| | | Shim | OK N-A | |
| | | Impeller Shaft Front Nut | | |
| | X | IMPELLER DR. (SINGLE-SPEED) | | |
| | | Drive Gear Teeth | OK | |
| | | Pinion Teeth | OK 33 | |
| | | Journals | | |
| | | IMP. DR. (TWO-SPEED, DUAL HYDR. CLUTCH TYPE) | | |
| | | Sleeve (Low-Speed) | — | |
| | | Piston and Lock (Low-Speed) | — | |
| | | Spring (Low-Speed) | — | |
| | | Thrust Spacer (Low-Speed) | — | |
| | | Thrust Washer (Low-Speed) | — | |
| | | Clutch Plates (Low-Speed) | — | |
| | | Clutch Discs (Low-Speed) | — | |
| | | Clutch Housing (Low-Speed) | — | |
| | | Sun Gear | — | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 9 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Inter. Impeller Drive Shaft Assy. | — | |
| | | Bushing | — | |
| | | Pinions | — | |
| | | Pinion Bushings | — | |
| | | Locks | — | |
| | | Inter- Impeller Drive Gear | — | |
| | | Spring (High-Speed) | — | |
| | | Clutch Disc Retainer (High-Speed) | — | |
| | | Clutch Plates (High-Speed) | — | |
| | | Clutch Discs (High-Speed) | — | |
| | | Adapter (High-Speed) | — | |
| | | Piston (High-Speed) | — | |
| | | Impeller Drive Gear | | |
| | | **TWO-SPEED CLUTCH CONTROL** | | |
| | | Housing or Subst. Cover | — | |
| | | Valve | — | |
| | | Spring | — | |
| | | Washer | — | |
| | | Sleeve | — | |
| | | **OIL PUMP BODY, GEARS, END PLATE AND COVER** | | |
| | | Finished Surfaces | K | |
| | | Studs | K | |
| | | Gear Recesses | K | |
| | | Oil Passages | K | |
| | | Drive Shaft | K | |
| | | Coupling Gears | K | |
| | | Coupling Gear Nut | K | |
| | | Suction Pump Idler Gear Shaft | K | |
| | | Suction Pump Idler Gear | K | |
| | | Pressure Pump Drive Gear | K | |
| | | Pressure Pump Idler Gear | K | |
| | | Oil Pump End Plate | K | |
| | | Oil Pump Cover | K | |
| | | Inlet and Outlet Flanges | K | |
| | | Plugs | K | |
| | | Check Valve Body | — | |

Inspected By .....

Approved By .....

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Engine No. .....

# ENGINE INSPECTION REPORT

Page No. 10 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | **OIL PUMP CHECK VALVE** | | |
| | | Valve | — | |
| | | Spring | — | |
| | | Retainer | — | |
| | | **OIL PRESSURE RELIEF VALVE** | | |
| | | Body | OK | |
| | | Valve | OK | |
| | | Spring | OK | |
| | | Lock Nut | OK 3 | |
| | | Adjusting Nut | OK | |
| | | Cap | OK | |
| | | Washers | OK | |
| | | **TACH. DR. GEAR HOUSING, GEARS AND COVER** | | |
| | | Housing | OK | |
| | | Tach. Dr. Gr. Shaft, Oil Seal Ring, Ret. | OK | |
| | | Mech. Tach. Dr. Shaft, Oil Seal Ring, Ret. | — | |
| | | Elec. Tach. Dr. Shaft, Oil Seal Ring, Ret. | — | |
| | | Tach. Dr. Gear Housing Cover | OK | |
| | | Mech. Tach. Drive Shaft Housing | — | |
| | | Elec. Tach. Subst. Cover | — | |
| | | **DUAL ACCESSORY DRIVE HOUSING** | | |
| | | Finished Surfaces | NG — Broken Boss on Housing | |
| | | Studs | | |
| | | Oil Passages | | |
| | | Plugs | | |
| | | Inter. Drive Shaft Bushing | | |
| | | Idler Gear Bushing | | |
| | | Upper Drive Gear Bushing | | |
| | | Lower Drive Gear Bushing | | |
| | | **DUAL ACC. DR. HOUSING COVER** | | |
| | | Finished Surfaces | OK | |
| | | Studs | OK | |
| | | Oil Passages | OK | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 11 Total Time Since Overhaul Date

Engine No. Model Type Work Order No.

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Plugs | OK | |
| | | Inter. Drive Shaft Bushing | OK | |
| | | Idler Gear Bushing | OK | |
| | | Upper Drive Gear Bushing | OK | |
| | | Lower Drive Gear Bushing | OK | |
| | | Upper Drive Subst. Cover | | |
| | | Lower Drive Subst. Cover | | |
| | | DUAL ACCESSORY DRIVE GEARS | | |
| | | Driving Gear | OK | |
| | | Teeth | OK | |
| | | Splines | OK | |
| | | Journals | OK | |
| | | Idler Gear | | |
| | | Teeth | OK | |
| | | Journals | OK | |
| | | Upper Drive Gear | | |
| | | Teeth | OK | |
| | | Journals | OK | |
| | | Splines | OK | |
| | | Coupling | | |
| | | Lower Drive Gear | OK | |
| | | Teeth | OK | |
| | | Splines | OK | |
| | | Coupling | | |
| | | Intermediate Gear | OK | |
| | | Teeth | OK | |
| | | Attaching Screws | | |
| | | CRANKSHAFT FRONT END | | |
| | | Crankpin | OK | |
| | | Journals | | |
| | | Front Main Brg. Journal O.D. | OK | |
| | | Threads | OK | |
| | | Splines | OK | |
| | | Oil Passages | OK | |
| | | Crankshaft Bushings | OK | |
| | | Front Counterweight | N-D-A | |
| | | Counterweight Bushings | OK | |
| | | Counterweight Pins | OK | |
| | | Counterweight Stop | | |

Inspected By Approved By

Engine No.

# ENGINE INSPECTION REPORT

Page No. 12 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Attaching Bolts | OK | |
| | | Attaching Nuts | OK | |
| | | Breather Tube | OK | |
| | | Breather Tube Rear Support or Substituting Plug | — | |
| | | Lock Screw | OK | |
| | | Crankpin Front Plug | OK | |
| | | Lock Screw | OK | |
| | | **CRANKSHAFT REAR** | | |
| | | Rear Main Brg. Journal ..... O.D. | — | |
| | | Threads | OK | |
| | | Rear Main Brg. Nut | OK | |
| | | Lock Screw | OK | |
| | | Splines | OK | |
| | | Acc. Dr. and Starter Shaft Coupling | OK | |
| | | Clamping Capscrew | OK | |
| | | Washer | — | |
| | | Bronze Crankshaft Bushings | — | |
| | | Floating Steel Crankshaft Bushings | — | |
| | | Rear Counterweight | OK | |
| | | Counterweight Bushings | N-D-A | |
| | | Counterweight Pins | OK | |
| | | Counterweight Stop | OK | |
| | | Attaching Bolts | OK | |
| | | Attaching Nuts | OK | |
| | | **FRONT MAIN BEARING** | | |
| | | Rollers | OK | |
| | | Outer Race ..... O.D. | — | |
| | | Inner Race ..... I.D. | — | |
| | | Retainer | OK | |
| | | **REAR MAIN BEARING** | | |
| | | Rollers | OK | |
| | | Outer Race ..... O.D. | — | |
| | | Inner Race ..... I.D. | — | |
| | | Retainer | OK | |
| | | **MASTER ROD** | | |
| | | Oil Passages | OK | |

Inspected By .....  Approved By .....

.....  Engine No. .....

# ENGINE INSPECTION REPORT

Page No. 13 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Piston Pin Bushing | OA | |
| | | Bearing | OA | |
| | | Alignment | — | |
| | | Twist | — | |
| | | Knuckle Pin Holes | OA | |
| | | Knuckle Pin Locking Plate | OA | |
| | | Lock Screws | OA | |
| | | End Seal Disc. | OA | |
| | | End Seal Spacer | OA | |
| | | Spring | OK | |
| | | **ARTICULATED RODS** | | |
| | | Piston Pin Bushings | OA | |
| | | Knuckle Pin Bushings | OA | |
| | | Alignment | OK | |
| | | Twist | OK | |
| | | Knuckle Pins | OK | |
| | | **CYLINDERS** | | |
| | | Cylinder Location | — | |
| | | Rocker Box Cover Surfaces | — | |
| | | Rocker Box Cover Studs | — | |
| | | Rocker Arm Bolt Bosses | — | |
| | | Rocker Arm Bolt Bushings | — | |
| | | Exh. Pipe Flange Mount. Pad | — | |
| | | Exh. Flange Studs | — | |
| | | Int. Pipe Flange Mount. Pad | — | |
| | | Int. Flange Screw Bushings | — | |
| | | Air Defl. Screw Bushings | — | |
| | | Cylinder Head | — | |
| | | Cylinder Head Fins | — | |
| | | Exhaust Valve Guide | — | |
| | | Intake Valve Guide | — | |
| | | Exhaust Valve Seat Insert | — | |
| | | Intake Valve Seat Insert | — | |
| | | Spark Plug Inserts | — | |
| | | Cylinder Air Test | — | |
| | | Cylinder Barrel Fins | — | |
| | | Cylinder Barrel Skirt | — | |
| | | Cylinder Mounting Flange | — | |
| | | Hold-Down Capscrews | — | |

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# ENGINE INSPECTION REPORT

Page No. 14 ..... Total Time ..... Since Overhaul ..... Date .....

Engine No. ..... Model ..... Type ..... Work Order No. .....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Corrosion in Bore | | |
| | | Scores in Bore | | |
| | | Ring Wear in Bore | | |
| | | Minimum Dia. of Bore | | |
| | | Maximum Dia. of Bore | | |
| | | Out of Round | | |
| | | Taper in Bore | | |
| | | **EXHAUST VALVES** | | |
| | | Valve Head | | |
| | | Face | | |
| | | Stem | | |
| | | Tip | | |
| | | Minimum Face Dia. | | |
| | | Tip Wear | | |
| | | Stretch | | |
| | | Valve Locks | | |
| | | Outer Valve Spring | | |
| | | Inter. Valve Spring | | |
| | | Inner Valve Spring | | |
| | | Valve Spring Washer | | |
| | | **INTAKE VALVES** | | |
| | | Valve Head | | |
| | | Face | | |
| | | Stem | | |
| | | Tip | | |
| | | Minimum Face Dia. | | |
| | | Tip Wear | | |
| | | Valve Locks | | |
| | | Outer Valve Spring | | |
| | | Inter. Valve Spring | | |
| | | Inner Valve Spring | | |
| | | Valve Spring Washers | | |
| | | **PISTONS** | | |
| | | Piston Location | | |
| | | Piston Head | | |
| | | Ring Grooves | | |
| | | Ring Lands | | |
| | | Skirt | | |

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## ENGINE INSPECTION REPORT

Page No. 15..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | Diameter | | |
| | | Piston Pin Holes | | |
| | | Retainer Grooves | | |
| | | Piston Pins | | |
| | | ROCKER BOX COVERS | | |
| | | Parting Surface | | |
| | | ROCKER ARMS | | |
| | | Roller | | |
| | | Hub | | |
| | | Pin | | |
| | | Oil Passages | | |
| | | Adjusting Screw | | |
| | | Clamping Screw | | |
| | | Rocker Arm Bearing | | |
| | | Rocker Arm Bolt | | |
| | | PUSH RODS | | |
| | | Ball Ends | | |
| | | PUSH ROD HOUSINGS | | |
| | | Clamps | | |
| | | INTAKE PIPES | | |
| | | Flange | | |
| | | Attaching Screws | | |
| | | CYLINDER HD. AIR DEFLECTORS | | |
| | | Rivet | | |
| | | Attaching Screws | | |
| | | INTER-CYLINDER AIR DEFLECTORS | | |
| | | Pad | | |
| | | Rivets | | |
| | | Grommet | | |
| | | Plate | | |
| | | Attaching Nut | | |
| | | Clamp | | |
| | | Clamp Bolt and Nut | | |
| | | Spacer | | |

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# ENGINE INSPECTION REPORT

Page No. 16..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| Part No. | Quan. | Part Name | Remarks | Disposition |
|---|---|---|---|---|
| | | OIL SUMP | | |
| | | Finished Surfaces | | |
| | | Oil Passages | | |
| | | Oil Strainer | | |
| | | Magnetic Oil Plug | | |
| | | Plugs | | |
| | | IGNITION WIRING MANIFOLD | | |
| | | Manifold Halves | | |
| | | Manifold Elbows | | |
| | | Manifold Support | | |
| | | Support Clips | | |
| | | Main Magneto Conduits | | |
| | | Cross-Over Conduit | | |
| | | Spark Plug Conduits | | |
| | | Spark Plug Terminal Elbows | | |
| | | Magneto Outlet Front Flanges | | |
| | | Magneto Outlet Elbows | | |

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## ENGINE INSPECTION REPORT

Page No. 17..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL SUB-ASSEMBLY INSPECTION | Mechanic | Inspector |
|---|---|---|
| **REDUCTION GEAR FRONT SECTION** | | |
| 1. Check propeller shaft, gears, bushings and front section for finish. | ..... | ..... |
| 2. Check through bolts for installation of locking circlets and lockwiring. | ..... | ..... |
| 3. Check hydro-control rings for side clearance, gap and gap location. | ..... | ..... |
| 4. Check fit of thrust bearing spacer on propeller shaft. | ..... | ..... |
| 5. Check clearance on all gears. Check for proper cotterpinning and lockwiring. | ..... | ..... |
| 6. Check installation of propeller shaft. | | |
| 7. Check thrust nut oil seal rings for side clearance, gap and gap location. | ..... | ..... |
| | ..... | ..... |
| **FRONT AND REAR MAIN SECTIONS** | | |
| 1. Check installation of locking of cam and cam drive gear. | ..... | ..... |
| 2. Check end clearance and blacklash of gears. | ..... | ..... |
| 3. Check for side clearance of connecting rods, locks, lockwiring and mutilation of knuckle pin faces. | ..... | ..... |
| 4. Check timing marks on gears and cam. | ..... | ..... |
| 5. Check all nuts and capscrews for proper locking. | ..... | ..... |
| **SUPERCHARGER FRONT SECTION** | | |
| 1. Check installation and tightness of supercharger front housing oil drain plug. | ..... | ..... |
| 2. Check supercharger front housing breather relief valve for location, operation and locking. | ..... | ..... |
| 3. See that breather screws and intake pipe packing and nuts are installed. | ..... | ..... |
| **SUPERCHARGER REAR SECTION** | | |
| 1. Check rear section and cover, gears and drives for proper finish. | ..... | ..... |
| 2. Check impeller end clearance. Check nut for tightness and locking. | ..... | ..... |

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# ENGINE INSPECTION REPORT

Page No. 18..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL SUB-ASSEMBLY INSPECTION | Mechanic | Inspector |
|---|---|---|
| **SUPERCHARGER REAR SECTION** | | |
| 3. Check staking and lockwiring of all screws and plugs. | ..... | ..... |
| 4. Check side clearance, gap and gap location of impeller shaft oil seal rings. | ..... | ..... |
| 5. Be sure all gaskets are installed. | ..... | ..... |
| 6. Check accessory drive gears for location, backlash and end clearance. | ..... | ..... |
| 7. Check rear section cover for lockwashers, palnuts, cotter-pins and lockwire. | ..... | ..... |
| 8. Check assembly and locking of supercharger drain valve. | ..... | ..... |
| 9. Check assembly and locking of dual accessory drive. | ..... | ..... |
| 10. Check depth dimension of starter coupling in extreme "In" position. | ..... | ..... |
| 11. Check depth dimension of starter coupling in extreme "Out" position. | ..... | ..... |
| **CYLINDERS, VALVES AND PISTONS** | | |
| 1. Check valves for proper location. | ..... | ..... |
| 2. Check assembly of valves, springs, washers and locks. Check for clearance between rocker arm and valve spring washer. | ..... | ..... |
| 3. Test valves for leaks under pressure. | ..... | ..... |
| 4. Check piston rings for side clearance and gap. Check etched mark "Top" for correct installation. | ..... | ..... |
| 5. Check for oil seals, locks, washers and springs. | ..... | ..... |
| **CRANKSHAFT AND MASTER ROD** | | |
| 1. Check crankshaft front and rear sections for engine assembly matching numbers. | ..... | ..... |
| 2. Check counterweights for assembly matching numbers, engine number and location on crankshaft. | ..... | ..... |
| 3. Check crankshaft and master rod for proper finish. | ..... | ..... |
| 4. Check counterweight pins for locking. | ..... | ..... |
| 5. Check knuckle pins for proper installation and locking. | ..... | ..... |
| 6. Witness tightening of rear half crankshaft bolt and check for stretch. | ..... | ..... |

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# ENGINE INSPECTION REPORT

Page No. 19..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL ENGINE ASSEMBLY INSPECTION | Mechanic | Inspector |
|---|---|---|
| 1. Check fit of main bearings on crankshaft. Check the freeness of bearing. | ..... | ..... |
| 2. Measure and record width of master rod assembly. | ..... | ..... |
| 3. Check and record crankpin and master rod diametrical and end clearances. Dia. . . . . End Cl. . . . . | ..... | ..... |
| 4. Check connecting rods for location in crankcase and verify engine number. | ..... | ..... |
| 5. Check crankshaft for alignment, runout, and end clearance, cotterpins and lockwire. | ..... | ..... |
| 6. Check assembly of inner race of bearing on crankshaft front section. | ..... | ..... |
| 7. Check bolting and locking of crankcase sections. | ..... | ..... |
| 8. Check timing marks on gears and cam. | ..... | ..... |
| 9. Check assembly and locking of reduction drive gear. | ..... | ..... |
| 10. Check crankshaft front section for nicks and burrs. | ..... | ..... |
| 11. Check lowering of front section. Be sure rubber oil seal rings are installed. | ..... | ..... |
| 12. Check pistons for location when assembling to rods. Be sure that piston pin locks and piston rings are properly installed and ring gaps properly spaced. | ..... | ..... |
| 13. Check cylinders for location at assembly, watch for broken piston rings and gaskets. | ..... | ..... |
| 14. Check tightness of cylinder hold-down cap screws. Record torque values. | ..... | ..... |
| Cylinder Location 1 2 3 4 5 6 7 8 9 | | |
| Torque Lbs | | |
| 15. Check lockwiring of cylinder hold-down cap screws. | ..... | ..... |
| 16. Check front supercharger housing for foreign particles. | ..... | ..... |
| 17. Check lowering of rear section, see that oil seal rings are properly spaced, are not broken and that all gaskets are in place. Check tightness and locking of attaching nuts and bolts. | ..... | ..... |
| 18. Check intake pipes for foreign particles and nuts for tightness. | ..... | ..... |
| 19. Check rocker arm mechanism for assembly and locking. | ..... | ..... |
| 20. Check push rod rubber hose and clamps for proper location and roundness. | ..... | ..... |
| 21. Check valve timing on No. 1 cylinder in firing order sequence. Record two readings. Inlet Open No. 1..... Exhaust Close No. 1..... | ..... | ..... |

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# ENGINE INSPECTION REPORT

Page No. 20..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL ENGINE ASSEMBLY INSPECTION | Mechanic | Inspector |
|---|---|---|
| 22. Check valve tappet clearance and position and tightness of adjusting screws. | ..... | ..... |
| 23. Check adjusting screw lock bolt and washer for tightness. | ..... | ..... |
| 24. Check magneto cam step alignment with lines on housing. Check magneto timing—record reading. Check tightness and locking of attaching nuts. | ..... | ..... |
| 25. Check magneto blocks for breakage, see that they are properly located. | ..... | ..... |
| 26. Check tightness of thrust nut. Check propeller shaft runout. | ..... | ..... |
| 27. Check radio shielding assembly for mutilation and clamps for proper location. | ..... | ..... |
| 28. Check inside of cylinders for foreign particles and assemble spark plugs immediately. | ..... | ..... |
| 29. Check inside of induction passages for foreign matter prior to installation of carburetor adapter and after installation. | ..... | ..... |
| 30. Check complete engine for lockwashers, palnuts, cotterpins and lockwire. | ..... | ..... |
| 31. Check installation, proper clearance, etc. of all air deflectors. | ..... | ..... |
| 32. Check the carburetor for part number, see that all parts are assembled to it and that the throttle and mixture controls work freely. | ..... | ..... |
| 33. See that accessories are installed as required. | ..... | ..... |
| **FINAL ENGINE PACKING INSPECTION** | | |
| 1. Temporary Slush. Any engine not packed within twenty-four hours after Final Test must have cyl. bores and exh. valve seats slushed. | ..... | ..... |
| 2. Magneto Timing — Left..... Right..... Marks on gear..... Cam flat with hsg. marks. Master Rod at Top Center in No.....cylinder. | ..... | ..... |
| 3. Impeller—Induction Chamber. | ..... | ..... |
| 4. Magneto—Indentations in coil plates by contact buttons. Interior of magnetos, gears, distributor, spring tension on contact points. Condition of both magneto blocks, interior of breaker box, breaker points and spring tension. | ..... | ..... |
| 5. Ignition wires for insulation and security in blocks. Installation of booster and ground connections. | ..... | ..... |
| 6. Ring out ignition, ground and booster wires. | ..... | ..... |
| 7. Terminals, springs, elbows and knurled nuts for condition. | ..... | ..... |

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## ENGINE INSPECTION REPORT

Page No. 21..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL ENGINE PACKING INSPECTION | Mechanic | Inspector |
|---|---|---|
| 8. Tightening of magneto attaching nut and application of cotterpins or lockwire. | ..... | ..... |
| 9. Oil Pump Relief Valve. | ..... | ..... |
| 10. Cuno Oil Filter. | ..... | ..... |
| 11. Magnetic Plug, Oil Sump Screen. | ..... | ..... |
| 12. Condition of thrust nut, propeller shaft threads and splines, spline locating pin; lockwire of breather screen and plug. | ..... | ..... |
| 13. Check and enter all accessory serial numbers. | ..... | ..... |
| 14. Fuel screen removal. Operation of all levers through entire range. Idle mix, control lever for range. | ..... | ..... |
| 15. Air scoop studs and application of gaskets and screen. After carburetor has been drained, slush and paint touch-up. Check all lockwires and cotterpins. | ..... | ..... |
| 16. Check slushing of rear section. | ..... | ..... |
| 17. Radio shielding, cylinder heads for condition, intake pipe packing nut condition, cap screws and washers. | ..... | ..... |
| 18. Priming system, condition and clearances. | ..... | ..... |
| 19. Cylinder hold-down cap screws, palnuts, lockwire, cotter pins, crankcase bolts, ignition wire clips, all cotter pins front and rear. | ..... | ..... |
| 20. Check slushing of front section. | ..... | ..... |
| 21. Valve clearance, rocker arm side play, lock bolts tight with minimum clearance in slot, lockwashers, installation of valve locks, interior of rocker box for clearance. Rocker arm bolts for cotter pins. Slushing of valve stems and rockers. | ..... | ..... |
| 22. Lockwire head baffles, safety-wire on sump screen, magnetic plug, front cover studs, square head pipe plugs, frt. section timing hole plug. | ..... | ..... |
| 23. Drain tube clamps. | ..... | ..... |
| 24. Head fins for mutilation, baffle clamps for location and tension; baffles for mutilation and clearance; hose clamps for type, location and tightness, ignition wire clamps for tightness. | ..... | ..... |
| 25. Ring out ignition, ground and booster wires. | ..... | ..... |
| 26. Installation of side drive subst. cover and synchronizers or covers for lockwire. | ..... | ..... |
| 27. Thrust nut—tight. | ..... | ..... |
| 28. Check inside all cyls. for foreign matter after checking slushing of cylinders. | ..... | ..... |
| 29. Check attached accessories and list. | ..... | ..... |
| 30. Ignition wires for insulation and security in blocks. Installation of booster and ground connections. | ..... | ..... |

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# ENGINE INSPECTION REPORT

Page No. 22..... Total Time..... Since Overhaul..... Date.....

Engine No..... Model..... Type..... Work Order No.....

| FINAL ENGINE PACKING INSPECTION | Mechanic | Inspector |
|---|---|---|
| 31. Bolts on engine mounting plate for tightness. | ..... | ..... |
| 32. Carburetor scoop and other openings properly covered. | ..... | ..... |
| 33. Rear ignition terminals attached to dummy plugs and slushing of external rear part of engine. | ..... | ..... |
| 34. Check each spark plug for type. Hex and threads. Witness oiling, packing and sealing of package. | ..... | ..... |
| 35. Tightening of magneto attaching nut and application of cotter pins or lock wire. | ..... | ..... |
| 36. Bolting of engine to cradle and int. pipes for damage. | ..... | ..... |
| 37. Front ign. terminals attached to dummy plugs. | ..... | ..... |
| 38. Check markings on shipment box for model of engine and engine number. | ..... | ..... |
| 39. Generator drive shaft; square-involute, splines; lockwire, oil seal. | ..... | ..... |
| 40. Attach. tags O.K.'ing for Storage. | ..... | ..... |

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# SECTION 4

# TABLES OF LIMITS

TL-30 Gun Synchronizer and Dual Accessory Drives

TL-38 Longitudinal and Accessory Drive Sections

TL-40 Two-Speed Supercharger (Plate Clutch Type)

TL-45 Tightening Torque Values

TL-75 Torque Indicator Crankcase Front Section for .5625 (16:9) and .666 (3:2) Reduction Geared Engines

TL-87 Two-Speed Supercharger (Roller Clutch Type)

## TABLE OF LIMITS 30

## GUN SYNCHRONIZER AND DUAL ACCESSORY DRIVES

**(Refer to Limits Chart No. 410150)**

**For Torque Values Refer to TL-45**

**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 1. | Accessory Drive Intermediate Shaft & Bushing—Dia. | .001L | .005L | .025L | .127L |
| 2. | Accessory Drive Intermediate Shaft Gear & Bushing—Dia. | .001L | .005L | .025L | .127L |
| 3. | Accessory Drive Shaft—End Clearance | .009L | .025L | .229L | .635L |
| 4. | Accessory Drive Shaft Sleeve & Bushing—Dia. | .002L | .006L | .051L | .152L |
| 5. | Accessory Drive Shaft—End Clearance | .007L | .025L | .178L | .635L |
| 6. | Vacuum Pump Shaft & Accessory Drive Shaft Spline —Side Clearance | .001L | .010L | .025L | .254L |
| 7. | Accessory Drive Shaft & Accessory Drive Intermediate Shaft Gear—Backlash | .004 | .020 | .102 | .508 |
| 8. | Accessory Drive Idler Gear & Bushing—Dia. | .002L | .008L | .051L | .203L |
| 9. | Accessory Drive Idler Gear—End Clearance | .006L | .040L | .152L | 1.016L |
| 10. | Accessory Drive Idler Gear Bushing—Dia. | .001T | .003T | .025T | .076T |
| 11. | Accessory Drive Intermediate Gear & Intermediate Shaft Gear—Backlash | .004 | .020 | .102 | .508 |
| 12. | Accessory Drive Intermediate Shaft & Bushing—Dia. | .002L | .008L | .051L | .203L |
| 13. | Accessory Drive Intermediate Shaft—End Clearance | .006L | .040L | .152L | 1.016L |
| 14. | Accessory Drive Intermediate Shaft Bushing—Dia. | .001T | .003T | .025T | .076T |
| 15. | Upper Vacuum Pump Drive Gear & Bushing—Dia. | .002L | .008L | .051L | .203L |
| 16. | Upper Vacuum Pump Drive Gear—End Clearance | .014L | .050L | .356L | 1.270L |
| 17. | Upper Vacuum Pump Drive Gear Bushing—Dia. | .001T | .003T | .025T | .076T |
| 18. | Accessory Drive Idler Gear & Upper & Lower Vacuum Pump Drive Gears—Backlash | .004 | .020 | .102 | .508 |
| 19. | Lower Vacuum Pump Drive Gear & Front Bushing—Dia. | .002L | .008L | .051L | .203L |
| 20. | Lower Vacuum Pump Drive Gear & Rear Bushing—Dia. | .004L | .010L | .102L | .254L |
| 21. | Lower Vacuum Pump Drive Gear—End Clearance | .011L | .050L | .279L | 1.270L |
| 22. | Lower Vacuum Pump Drive Gear Front Bushing & Housing—Dia. | .001T | .003T | .025T | .076T |
| 23. | Lower Vacuum Pump Drive Gear Rear Bushing & Cover—Dia. | .002T | .004T | .051T | .102T |
| 24.* | Upper Vacuum Pump Drive Gear Bushing—Dia. (Rear) | .002T | .004T | .051T | .102T |
| 25.* | Upper Vacuum Pump Drive Gear & Bushing—Dia. | .004L | .010L | .102L | .254L |
| 26.* | Upper Vacuum Pump Drive Gear—End Clearance | .011L | .050L | .279L | 1.270L |
| 27. | Synchronizer Drive Shaft Support & Bushing—Dia. | .001T | .003T | .025T | .076T |
| 28. | Synchronizer Drive Shaft & Bushing—Dia. | .001L | .008L | .025L | .203L |

**TABLE OF LIMITS 30 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 29. | Synchronizer Drive Shaft—End Clearance | .014L | .055L | .356L | 1.397L |
| 30. | Synchronizer Cam & Roller (With plunger in locked position) | .002L | .010L | .051L | .254L |
| 31. | Synchronizer Roller & Plunger—Dia. | .001L | .004L | .025L | .102L |
| 32. | Synchronizer Roller & Plunger—Side Clearance | .003L | .012L | .076L | .305L |
| 33. | Synchronizer Housing & Plunger—Dia. | .0005l | .005L | .013L | .127L |
| 34. | Synchronizer Plunger & Lower Housing—Side Clearance | .001L | .020L | .025L | .508L |

**NOTES**

| | |
|---|---|
| 24, 25 | For involute coupling drive. (Standard and special ratio accessory drive shafts.) |
| 26 | For special accessory drive shaft with a ratio of 1.636:1. |

## TABLE OF LIMITS 38
## LONGITUDINAL AND ACCESSORY DRIVE SECTIONS
**(Refer to Limits Chart No. 413222)**
**For Torque Values Refer to TL-45**
**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 1. | Rocker Roller Hub & Pin—dia. | .001T | .002L | .025T | .051L |
| 2. | Rocker Roller Hub & Rocker Roller—dia. | .0015L | .020L | .038L | .508L |
| 3. | Rocker Roller Hub & Rocker Arm—Side Clearance | Rivet | Tight | Rivet | Tight |
| 4. | Rocker Roller & Rocker Arm—Side Clearance | .0095L | .050L | .241L | 1.270L |
| 5. | Rocker Bearing & Rocker Box—Side Clearance before Clamping | .001L | .015L | .025L | .381L |
| 5a. | Rocker Bearing—Inner Races Clamped—End Clearance | Clamp Tight | .010L | Clamp Tight | .254L |
| 6. | Rocker Arm Bearing & Rocker—dia. | .0018T | .000 | .046T | .000 |
| 7. | Rocker Arm Bearing & Rocker Bolt—dia. | .000 | .004L | .000 | .102L |
| 8. | Rocker Bolt & Cylinder Head—dia. | .0005L | .005L | .013L | .127L |
| 10. | Rocker Arm Bearing—Internal End Play—Out of Rocker Arm | .008L | .019L | .203 | .483 |
| 11. | Rocker Arm Bearing—Internal End Play in Rocker Arm with Rocker Arm Bolt Inserted in Bearing | Free | .012 | Free | .305 |
| 12.* | Valve Spring Tension | | | | |
| 13. | Intake Valve & Valve Guide | | | | |
| | Center—dia. | .002L | .008L | .051L | .203L |
| | End—dia. | .002L | .010L | .051L | .254L |
| 14.* | Exhaust Valve & Valve Guide | | | | |
| | Center—dia. | .0035L | .008L | .089L | .203L |
| | End—dia. | .0035L | .010L | .089L | .254L |
| 15. | Intake Valve Guide & Cylinder Head—dia. | .001T | .003T | .025T | .076T |
| 16. | Exhaust Valve Guide & Cylinder Head—dia. | .003T | .0045T | .076T | .114T |
| 17. | Valve Seat in Cylinder Head | | | | |
| | Intake—dia. | .009T | .013T | .229T | .330T |
| | Exhaust—dia. | .0095T | .0135T | .241T | .343T |
| 18. | Governor Drive Shaft Bushing and Crankcase—dia. | .001T | .003T | .025T | .076T |
| 19. | Governor Drive Shaft and Bushing—dia. | .002L | .006L | .051L | .152L |
| 20. | Governor Drive Gear & Governor Interm. Drive Gear—Backlash | .004 | .026 | .102 | .660 |
| 21.* | Piston Groove No. 1 (Top) & Ring—Side Clearance | .011L | .013L | .279L | .330L |
| 21a.* | Piston Groove No. 1 (Top) & Ring—(Wedge Type)—Side Clearance | .005L | .009L | .127L | .229L |
| 22.* | Piston Groove No. 2 & Ring—Side Clearance | .011L | .013L | .279L | .330L |
| 22a.* | Piston Groove No. 2 & Ring—(Wedge Type)—Side Clearance | .005L | .009L | .127L | .229L |
| 23.* | Piston Groove No. 3 & Ring—Side Clearance | .008L | .010L | .203L | .254L |
| 23a.* | Piston Groove No. 3 & Ring—(Wedge Type)—Side Clearance | .005L | .009L | .127L | .229L |
| 24.* | Piston Groove No. 4 & Ring—Side Clearance | .011L | .013L | .279L | .330L |
| 24a.* | Piston Groove No. 5 & Ring—Side Clearance | .011L | .013L | .279L | .330L |
| 25.* | Piston Groove No. 6 & Ring—Side Clearance | .006L | .008L | .152L | .203L |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Min. Inches | Max. Inches | Min. Millimeters | Max. Millimeters |
|---|---|---|---|---|---|
| 26. | Piston Ring—Compression & Oil Rings—Gap | .044 | | 1.1176 | |
| 27. | Piston Pin & Piston—dia. | .000 | .004L | .000 | .102L |
| 28. | Piston Pin Bushing & Piston Pin—dia. | .002L | .008L | .051L | .203L |
| 29. | Piston & Cylinder Barrel Diameter—Center of Skirt | .023L | .037L | .584L | .940L |
| 30. | Cylinder Barrel Bore—Taper | | .010 | | .254 |
| | Cylinder Barrel Bore—Wear | | .010 | | .254 |
| 31. | Cylinder Barrel Bore—Out of Round | | .005 | | .127 |
| 32. | Piston Pin Bushing & Conn. Rod.—dia. | .004T | .0065T | .102T | .165T |
| 33. | Master Rod & Bearing—dia. | .0025T | .0045T | .064T | .114T |
| 33a. | Master Rod & Bearing (Loose Prefit Bearing)—dia. | .0005L | .0025L | .013L | .064L |
| 34. | Master Rod & Knuckle Pin Bushing—Side Clearance | .007L | .030L | .178L | .762L |
| 35. | Art. Rod & Knuckle Pin Bushing—dia. | .004T | .0065T | .102T | .165T |
| 36. | Knuckle Pin & Bushing—dia. | .003L | .0055L | .076L | .140L |
| 37.* | Master Rod & Knuckle Pin—dia. | .0005T | .0015T | .013T | .038T |
| 38. | Master Rod Oil Seal Disk Lugs & Knuckle Pin Locking Pin Locking Plate Lugs—Side Clearance | .005L | .030L | .127L | .762L |
| 39. | Master Rod Oil Seal Disk Spring Load When Compressed to .32 in. (8.12 mm) Height | 6 lb | 10 lb | 2.72 kg | 4.54 kg |
| 40. | Knuckle Pin Locking Plate and Master Rod Oil Seal Disk (Aluminum)—dia. | .002L | .008L | .051L | .203L |
| 40a. | Knuckle Pin Locking Plate & Master Rod Oil Seal Disk (Steel)—dia. | .0005L | .005L | .013L | .127L |
| 41. | Master Rod & Knuckle Pin Locking Plate—dia. | .0005T | .0015L | .013T | .038L |
| 42. | Master Rod & Master Rod Spacer—dia. | .0005L | .008L | .013L | .203L |
| 43. | Crankpin Bearing—End Play—End Play to be Measured with Master Rod in Extreme Forward Position | .010L | .045L | .254L | 1.143L |
| 44. | Valve Tappet Spring—Wire Diameter .063 in. (1.60 mm) Tension at 2.14 in. (54.3 mm) Height | 9.0 lb | 10.5 lb | 4.08 kg | 4.76 kg |
| 45. | Valve Tappet & Ball Socket—dia. | .0012L | .0027L | .030L | .069L |
| 46. | Valve Tappet & Guide—dia. | .001L | .0035L | .025L | .089L |
| 47. | Valve Tappet Guide & Crankcase Front Section—dia. | .000 | .002L | .000 | .051L |
| 48. | Valve Tappet Roller & Bushing—dia. | .001L | .005L | .025L | .127L |
| 49. | Valve Tappet Roller & Roller Bush.—Side Clearance | .0075L | .015L | .191L | .381L |
| 50. | Valve Tappet Roller Pin & Guide—Side Clearance | .005L | .016L | .127L | .406L |
| 51. | Valve Tappet Roller Pin & Bushing & Valve Tappet—dia. | .0025L | .006L | .064L | .152L |
| 52. | Cam & Cam Drive Pinion—Backlash | .008 | .024 | .203 | .610 |
| 53. | Cam Drive Pinion & Cam Drive Gear Bracket—Side Clearance | .009L | .025L | .229L | .635L |
| 54. | Cam Drive Gear Bracket & Bushing—dia. | .0025T | .004T | .064T | .102T |
| 55. | Cam Drive Gear & Bushing—dia. | .001L | .008L | .025L | .203L |
| 56. | Cam Drive Gear Bracket & Spacer—dia. | .0005L | .006L | .013L | .152L |
| 57. | Cam Drive Gear & Reduction Driving Gear—Backlash | .004 | .025 | .102 | .635 |
| 58. | Cam & Cam Bearing Ring—End Clearance | .002L | .015L | .051L | .381L |
| 59. | Cam & Cam Bearing Ring—dia. | .009L | .015L | .229L | .381L |
| 60. | Cam Bearing Ring & Crankcase Main Section—dia. | .001T | .002L | .025T | .051L |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Min. Inches | Max. Inches | Min. Millimeters | Max. Millimeters |
|---|---|---|---|---|---|
| 61. | Bearing and Crankcase Front Main Bearing Ring—dia. | .002L | .006L | .051L | .152L |
| 62. | Crankcase Front Main Bearing Ring & Crankcase Main Section—dia. | .001T | .002L | .025T | .051L |
| 63. | Crankcase Front Main Bearing Ring & Crankcase Main Section—dia. | .001L | .005L | .025L | .127L |
| 64. | Crankshaft Oil Seal Ring Spacer & Crankshaft Front End—dia. | .0005L | .003L | .013L | .076L |
| 65. | Oil Seal Ring & Crankshaft Oil Seal Ring Spacer—Side Clearance | .001L | .015L | .025L | .381L |
| 66. | Crankshaft Oil Seal Ring—(Hand Fit)—Gap | .018 | .020 | .457 | .508 |
| 67. | Bearing & Crankshaft Front End—dia. | .0002T | .0016T | .005T | .040T |
| 68. | Reduction Gear Drive Pinion Bushing & Propeller Shaft Arm—(Shrink Fit)—dia. | .002T | .004T | .051T | .102T |
| 69. | Reduction Gear Drive Pinion & Bushing—dia. | .002L | .006L | .051L | .152L |
| 70. | Reduction Gear Drive Pinion & Propeller Shaft Arm—Side Clearance | .006L | .025L | .152L | .635L |
| 71. | Reduction Driving Gear & Pinion—Backlash | .007 | .020 | .178 | .508 |
| 72. | Stationary Reduction Gear & Pinion—Backlash | .005 | .018 | .127 | .457 |
| 73. | Propeller Shaft Thrust Bearing Spacer & Propeller Shaft (Select to Obtain)—dia. | .001T | .001L | .025T | .025L |
| 74. | Propeller Shaft Thrust Bearing—End Movement | .0056 | .0191 | .142 | .485 |
| 75. | Propeller Shaft Thrust Bearing Spacer & Oil Seal Ring—Side Clearance | .001L | .010L | .025L | .254L |
| 76. | Propeller Shaft Thrust Bearing Spacer Oil Seal Ring—(Hand Fit)—Gap | .012 | .013 | .305 | .330 |
| 77. | Propeller Shaft & Thrust Bearing—dia. | .0002T | .0016T | .005T | .041T |
| 78. | Propeller Shaft Thrust Bearing Retainer & Crankcase Front Section—dia. | .003T | .008T | .076T | .203T |
| 79. | Propeller Shaft Thrust Bearing Retainer & Bearing—dia. | .0004L | .003L | .010L | .076L |
| 80. | Propeller Shaft Thrust Bearing and Retainer—Side Clearance | .0001T | .0059L | .003T | .150L |
| 81. | Propeller Shaft Thrust Bearing Nut Oil Seal Ring—Side Clearance | .003L | .015L | .076L | .381L |
| 82. | Propeller Shaft Thrust Bearing Nut Oil Seal Ring—(Hand Fit)—Gap | .003 | .015 | .076 | .381 |
| 84. | Spline Side Clearance, Movement of Propeller Hub on Propeller Shaft Measured at 15 in. (381 mm) Radius from Center of Propeller Shaft | | .040 | | 1.016 |
| 85. | Allowable Runout of Propeller Shaft Between Threads & Splines at Forward End When in Position in Engine | .012 Full Indicator Reading | | .305 Full Indicator Reading | |
| 86.* | Propeller Shaft—Total Radial Looseness | | .015 | | .381 |
| 87. | Propeller Shaft & Sleeve—dia. | .0015T | .0045T | .038T | .114T |
| 88. | Propeller Shaft Sleeve & Front Bushing—dia. | .0015T | .0035T | .038T | .089T |

## TABLE OF LIMITS 38 Continued

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 89. | Crankshaft Front End & Propeller Shaft Bushing—dia. | .0025L | .006L | .064L | .152L |
| 90. | Allowable Runout of Crankshaft at Front & Rear Propeller Shaft Bushing Locations When Supported at Main Front & Rear Bearings | .006 Full Indicator Reading | | .152 Full Indicator Reading | |
| 91. | Propeller Shaft & Rear Bushing—dia. | .0015T | .0045T | .038T | .114T |
| 92. | Crankshaft Front End & Prop. Shaft Rear Bushing—dia. | .003L | .008L | .076L | .203L |
| 96. | Crankcase Front Section & Crankcase Main Front Section—dia. | .002T | .006L | .051T | .152L |
| 98.* | Crankpin Bearing & Crankpin—Diameter (Select at Ass'y.)—dia. | .0038L | .0065L | .097L | .165L |
| 98a. | Crankpin Bearing & Crankpin (Loose Prefit Bearing)—dia. | .004L | .0065L | .102L | .165L |
| 99. | Front Counterweight & Stop | .0455L | .072L | 1.156L | 1.829L |
| 100. | Front Crankshaft & Counterweight Pin Bushing—dia. | .001T | .0025T | .025T | .064T |
| 101. | Front Counterweight & Bushing—dia. | .0015T | .003T | .038T | .076T |
| 102. | Rear Crankshaft & Counterweight Pin Bushing—dia. | .001T | .0025T | .025T | .064T |
| 103. | Rear Counterweight & Bushing—dia. | .0015T | .003T | .038T | .076T |
| 104. | Rear Counterweight & Stop | .0215L | .046L | .546L | 1.168L |
| 105. | Crankcheek to Cap Screw—Stretch | .008 | .009 | .203 | .2286 |
| 106. | Crankshaft Front & Crankshaft Rear (Before Tightening Cap Screw)—dia. | .001T | .002L | .025T | .051L |
| 107. | Crankcase Main Rear & Rear Bearing Ring—dia. | .004T | .006T | .102T | .152T |
| 108. | Crankcase Main Rear Bearing Ring & Bearing—dia. | .004L | .008L | .102L | .203L |
| 109. | Crankshaft Rear & Bearing—dia. | .001T | .0024T | .025T | .061T |
| 110. | Crankshaft End Play on Crankcase Main Section | .014L | .051L | .356L | 1.295L |
| 111. | Accessory Drive & Starter Coupling & Rear Crankshaft—dia. | .000 | .001T | .000 | .025T |
| 112. | Generator Gear Bushing & Supercharger Rear Cover—dia. | .0015T | .0035T | .038T | .089T |
| 113. | Generator Gear & Bushing—dia. | .001L | .008L | .025L | .203L |
| 114. | Diffuser Plate Vanes & Supercharger Front Housing | .005T | .012T | .127T | .305T |
| 115. | Generator Gear—End Clearance | .007L | .045L | .178L | 1.143L |
| 116. | Generator & Magneto Drive Oil Seal Spring, Wire Diameter .091 in. (2.31 mm)—Tension at 36 in. (9.14 mm)—Height | 8.5 lb | | 3.86 kg | |
| 117. | Generator Drive Oil Seal Collar & Generator Gear—dia. | .0005T | .0015T | .013T | .038T |
| 118. | Supercharger Inter. Gear 7:1 Ratio & Generator Gear—Backlash | .006 | .025 | .152 | .635 |
| 119. | Inter. Impeller Drive Shaft Rear Bushing & Supercharger Rear Cover—dia. | .001T | .003T | .025T | .076T |
| 120. | Impeller Clutch & Pinion Shaft & Inter. Impeller Drive Shaft Rear Bushing—dia. | .0005L | .005L | .013L | .127L |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 124. | Inter. Impeller Drive Shaft Propeller End Bushing & Supercharger Rear Housing—dia. | .001T | .004T | .025T | .102T |
| 128. | Supercharger Inter. Gear & Acc. Dr. Gear—Backlash | .006 | .025 | .152 | .635 |
| 129. | Supercharger Inter. Gear & Imp. Dr. Shaft Gear 7:1 Ratio—Backlash | .004 | .018 | .102 | .457 |
| 130. | Acc. Dr. Gear Spring Wire Dia. .225 in. (5.71 mm) Tension at 1.544 in. (39.21 mm) Height | 530 lbs | 625 lbs | 240 kg | 283 kg |
| 131. | Impeller Shaft Retainer & Oil Seal Ring—Side Clearance | .002L | .011L | .051L | .279L |
| 132. | Impeller Shaft Retainer Oil Seal Ring—Gap—Hand Fit | .006 | .008 | .152 | .203 |
| 133. | Accessory Drive & Starter Shaft—(Machine in Assembly)—Side Clearance | .020L | .040L | .508L | 1.016L |
| 134. | Accessory Drive & Starter Shaft Bushing & Supercharger Rear Cover—dia. | .005T | .007T | .127T | .178T |
| 135. | Accessory Drive & Starter Shaft & Bushing—dia. | .002L | .006L | .051L | .152L |
| 136. | Accessory Drive & Starter Shaft & Starter Coupling (12 jaw)—dia. | .0005L | .003L | .0127L | .076L |
| 137. | Accessory Drive & Starter Shaft to Starter Coupling & Spacer—dia. | .005L | .025L | .127L | .635L |
| 138. | Accessory Drive & Starter Shaft & Impeller Shaft Rear Bushing—dia. | .002L | .006L | .051L | .152L |
| 139. | Impeller Drive Shaft Gear & Front & Rear Bushing—dia. | .002T | .004T | .051T | .102T |
| 140. | Accessory Drive & Starter Shaft & Imp. Shaft Front Bushing—dia. | .0025L | .006L | .064L | .152L |
| 141. | Impeller Drive Shaft Gear & Rear Oil Seal Sleeve—dia. | .000 | .004L | .000 | .102L |
| 142. | Supercharger Housing Rear Sleeve & Supercharger Rear Housing—dia. | .001T | .003T | .025T | .076T |
| 143. | Impeller Oil Seal Ring & Impeller Shaft Oil Seal Sleeve Front & Rear—Side Clearance | .005L | .009L | .127L | .229L |
| 144. | Impeller Oil Seal Ring—Front & Rear Gap—Hand Fit | .010 | .0135 | .254 | .343 |
| 145. | Impeller Drive Shaft Gear—End Clearance | .012L | .017L | .305L | .432L |
| 146. | Impeller Drive Shaft Gear & Impeller Shaft Oil Seal Front Sleeve—dia. | .000 | .004L | .000 | .102L |
| 147. | Accessory Drive & Starter Shaft & Coupling Ring—Side Clearance | .002L | .008L | .051L | .203L |
| 148. | Starter Shaft & Coupling Ring—Gap | .0006 | .004 | .015 | .102 |
| 149.* | Impeller & Front Supercharger Housing—Side Clearance | .050L | | 1.270L | |
| 150.* | Impeller & Diffuser Plate—Side Clearance | .030L | .066L | .762L | 1.676L |
| 151. | Magneto Drive Oil Seal Collar & Magneto & Gun Synchronizer Drive Shaft—dia. | .0005T | .0025T | .013T | .064T |
| 152. | Magneto Drive Shaft Bushing & Supercharger Rear Cover—dia. | .001T | .003T | .025T | .076T |
| 153. | Magneto Drive Shaft & Bushing—dia. | .001L | .008L | .025L | .203L |
| 154. | Magneto Drive Shaft—End Clearance | .005L | .050L | .127L | 1.270L |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 155. | Gun Synchronizer Drive Shaft Thrust Bearing & Supercharger Rear Cover—dia. | .001T | .003T | .025T | .076T |
| 156. | Magneto Drive Shaft Gear & Synchronizer Drive Gear—Backlash | .004 | .025 | .102 | .635 |
| 157. | Magneto Drive Gear & Pump Drive Gear—Backlash | .004 | .025 | .102 | .635 |
| 158. | Magneto & Gun Synchronizer Drive Shaft & Plug—dia. | .0005T | .0035T | .013T | .089T |
| 159. | Supercharger Front Housing Breather Relief Valve Spring Wire dia. .030 in. (0.762 mm), Tension at .50 in. (1.270 mm) Height | .35 lbs | .56 lbs | .158 kg | .254 kg |
| 160. | Fuel Pump Drive Shaft Support & Bushing—dia. | .001T | .003T | .025T | .076T |
| 161. | Fuel Pump Drive Shaft & Bushing—dia. | .001L | .005L | .025L | .127L |
| 162. | Fuel Pump Drive Shaft Support & Supercharger Rear Cover—dia. | .000 | .004L | .000 | .102L |
| 163. | Fuel Pump Drive Shaft & Plug—dia. | .0005T | .002T | .013T | .051T |
| 164. | Gun Synchronizer Drive Shaft Thrust Bushing & Supercharger Rear Cover—dia. | .001T | .003T | .025T | .076T |
| 165. | Fuel Pump Drive Shaft—End Clearance | .011L | .040L | .279L | 1.016L |
| 166. | Oil Filter Bushing & Oil Filter—dia. | .000 | .0025L | .000 | .064L |
| 167. | Pump Drive Gear & Magneto Drive Gear—Backlash | .005 | .025 | .127 | .635 |
| 168. | Pump Drive Gear & Accessory Drive Gear—Backlash | .005 | .025 | .127 | .635 |
| 169. | Accessory Drive Gear & Accessory Gear—Backlash | .004 | .025 | .102 | .635 |
| 170. | Oil Pump Drive Shaft & Cover—dia. | .002L | .015L | .051L | .381L |
| 171. | Oil Pump Drive Shaft & Oil Pump Body—dia. | .002L | .015L | .051L | .381L |
| 172. | Oil Pump Drive Shaft & Oil Pump Body End Plate—dia. | .002L | .015L | .051L | .381L |
| 173. | Oil Pump Suction Drive Gear & Oil Pump Body—dia. | .001L | .007L | .025L | .178L |
| 174. | Oil Pump Pressure Gears & Body—End Clearance | .0035L | .013L | .089L | .330L |
| 175. | Oil Pump Suction Gears & Body—End Clearance | .0065L | .012L | .165L | .305L |
| 176.* | Oil Suction Pump Drive Gear & Idler Gear—Backlash | .004 | .020 | .102 | .508 |
| 177.* | Oil Pressure Pump Drive Gear & Driven Gear—Backlash | .004 | .020 | .102 | .508 |
| 178. | Oil Pump Driven Pressure Gear & Pump Body—dia. | .002L | .010L | .051L | .254L |
| 179. | Oil Pump Driven Pressure Gear & Pump Cover—dia. | .002L | .010L | .051L | .254L |
| 180. | Oil Pump Idler Gear Shaft & Pump Body—dia. | .001T | .0025T | .025T | .064T |
| 181. | Oil Pump Idler Gear Shaft & Pump End Plate—dia. | .0005T | .002L | .013T | .051L |
| 182. | Oil Pump Idler Gear & Idler Gear Shaft—dia. | .0015L | .008L | .038L | .203L |
| 183. | Pump Drive Gear & Bushing—dia. | .001L | .008L | .025L | .203L |
| 184. | Pump Drive Gear Bushing & Supercharger Rear Cover—dia. | .001T | .0035T | .025T | .089T |
| 185. | Pump Drive Gear—End Clearance | .028L | .060L | .711L | 1.524L |
| 186. | Pump Drive Gear & Plug—dia. | .0005T | .0035T | .013T | .089T |
| 187. | Tachometer Drive Oil Seal Thrust Spring-Wire Dia. .048 in. (1.21 mm) Tension at .50 in. (1.27 mm) Height | 4.50 lbs | 5.50 lbs | 20.41 kg | 24.95 kg |
| 188. | Tachometer Drive Shaft Bushing & Oil Pump Cover —dia. | .001T | .003T | .025T | .076T |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 189. | Tachometer Drive Shaft & Large Bushing—dia. | .001L | .006L | .025L | .152L |
| 190. | Tachometer Drive Shaft Bushing & Tachometer Drive Housing Cover—dia. | .001T | .003T | .025T | .076T |
| 191. | Tachometer Drive Shaft & Small Bushing—dia. | .002L | .005L | .051L | .127L |
| 192. | Tachometer Drive Shaft Housing & Bushing—dia. | .001T | .0035T | .025T | .089T |
| 193. | Tachometer Drive Shaft & Sleeve Shoulder End—dia. | .0005T | .0035T | .089T | .013T |
| | Outer End—dia. | .0015L | .0035T | .089T | .038L |
| 194. | Tachometer Drive Shaft Sleeve & Bushing—dia. | .003L | .006L | .076L | .152L |
| 195. | Oil Pump Drive Shaft & Tachometer Drive Shaft—Backlash | .004 | .020 | .102 | .508 |
| 196. | Oil Pressure Relief Valve & Body—dia. | .0025L | .006L | .064L | .152L |
| 197. | Oil Pressure Relief Valve Spring Wire Dia. .063 in. (1.60 mm) Tension at 1.406 in. (35.712 mm) Hgt. | 20 lbs | 24 lbs | 9.07 kg | 10.89 kg |
| 198. | Fuel Pump Tachometer & Spare Drive Shaft—End Clearance | .020L | .060L | .508L | 1.524L |
| 199. | Tachometer Drive Shaft & Oil Seal Thrust Spring Bushing—dia. | .001T | .0025T | .025T | .064T |
| 200. | Tachometer Drive Oil Seal Thrust Spring Retainer & Bushing—dia. | .003L | .008L | .076L | .203L |
| 201. | Oil Suction Pump Idler Gear & Body—End Clearance | .0065L | .015L | .165L | .381L |
| 202. | Oil Pressure Pump Drive Gear & Body—dia. | .0007L | .012L | .018L | .305L |
| 203. | Tachometer Drive Bushing I. D. Prop. End & Tachometer Driveshaft | .002L | .005L | .051L | .127L |
| 204. | Oil Pressure Pump Idler Gear & Body End Clearance | .0055L | .014L | .140L | .356L |
| 205. | Oil Pressure Relief Valve Spring—Wire dia. .063 in. (1.60 mm) Tension at 1.38 in. (35.05 mm) | 6 lbs | 8 lbs | 2.72 kg | 3.63 kg |
| 206. | Oil Pressure Relief Valve Body & Oil Pressure Relief Valve—dia. | .000 | .003L | .000 | .076L |
| 207. | Oil Pump Check Valve Spring—Wire dia. .047 in. (1.194) Tension at 2 in. (50.8 mm) Height | 3.50 lbs | 4.00 lbs | 1.59 kg | 1.81 kg |
| 208. | Oil Pressure Pump Drive Gear & Oil Pump Cover—dia. | .002L | .010L | .051L | .254L |
| 209. | Oil Pressure Pump Drive Gear & Body—End Clearance | .0055L | .014L | .140L | .356L |
| 210. | Oil Suction Pump Idler Gear & Body—dia. | .0012L | .012L | .030L | .305L |
| 211. | Oil Pump Driveshaft & Oil Pressure Pump Drive Gear—dia. | .0005L | .002L | .013L | .051L |
| 212. | Tachometer Driveshaft Housing & Tachometer Driveshaft Housing Cover—dia. | .0035L | .0005T | .089L | .013T |
| 213. | Oil Pump Driveshaft & Oil Suction Pump Idler Gear —Backlash | .004 | .020 | .102 | .508 |
| 214. | Tachometer Drive Gear Shaft & Oil Pressure Pump Drive Gear—dia. | .0005L | .002L | .013L | .051L |
| 215. | Tachometer Drive Gear Shaft & Tachometer Driveshaft—Backlash | .004 | .020 | .102 | .508 |
| 216. | Tachometer Drive Gear Shaft & Tachometer Drive Oil Seal Thrust Spring Retainer | .003L | .005L | .076L | .127L |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 217. | Oil Pressure Pump Idler Gear & Body—dia. | .001L | .012L | .025L | .305L |
| 218. | Oil Pressure Pump Idler Gear & Oil Pressure Pump Drive Gear—Backlash | .004 | .020 | .102 | .508 |
| 219. | Oil Pump Driveshaft & Body—End Clearance | .0065L | .015L | .165L | .381L |
| 220. | Oil Pressure Pump Idler Gear & Body (Hole)—dia. | .002L | .010L | .051L | .254L |
| 221. | Oil Pressure Pump Idler Gear & Oil Pump Cover (Hole) | .002L | .010L | .051L | .254L |
| 222. | Oil Suction Pump Idler Gear Shaft & Body—(Hole)—dia. | .001T | .0025T | .025T | .064T |
| 223. | Oil Suction Pump Idler Gear Shaft & Oil Suction Pump Idler Gear—dia. | .0015L | .008L | .038L | .203L |
| 224. | Oil Pump Cover & Tach. Drive Bushing O. D. Prop. End—dia. | .001T | .003T | .025T | .076T |
| 225. | Tachometer Drive Bushing I. D. Anti-Propeller End & Tachometer Driveshaft—dia. | .002L | .005L | .051L | .127L |
| 226. | Tachometer Drive Gear Shaft & Mechanical Tachometer Drive Shaft—Backlash | .004 | .020 | .102 | .508 |
| 227. | Oil Pump Check Valve Body & Oil Pump Check Valve—dia. | .020L | .036L | .508L | .914L |
| 228. | Oil Pump Check Valve Body & Oil Pump Check Valve Oil Seal Ring—Side Clearance | .002L | .006L | .051L | .152L |
| 229. | Oil Pump Check Valve Body & Pump Body—dia. | .001T | .0025T | .0254T | .064T |
| 230. | Oil Pump Check Valve Oil Seal Ring—Gap | .0065 | .020 | .165 | .508 |
| 231. | Impeller & Shaft (Impeller Must Be a Tight Fit on Splines) | | | | |
| 248. | Propeller Shaft Thrust Bearing Spacer Oil Seal Ring—Gap (Hand Fit) | .012 | .013 | .305 | .330 |
| 249. | Propeller Shaft Thrust Bearing Spacer—Oil Seal Ring—Side Clearance | .001L | .010L | .025L | .254L |
| 250. | Stationary Red. Gear Support & Sleeve—dia. | .005T | .007T | .127T | .178T |
| 251. | Reduction Gear Pinion & Bushing—Side Clearance | .004L | .010L | .102L | .254L |
| 252. | Reduction Gear Pinion & Bushing—dia. | .0025L | .0035L | .064L | .089L |
| 253. | Reduction Driving Gear & Pinion—Backlash | .011 | .027 | .279 | .686 |
| 254. | Reduction Gear Pinion Bushing & Red. Gear Pinion Carrier | | | | |
| | Small End—dia. | .001L | .006L | .025L | .152L |
| | Large End—dia. | .002L | .006L | .051L | .152L |
| 255. | Stationary Reduction Gear & Pinion—Backlash | .011 | .025 | .279 | .635 |
| 256. | Propeller Shaft & Thrust Bearing Spacer (16:9 Reduction)—dia. | .001T | .001L | .0254T | .0254L |
| 257. | Interm. Imp. Drive Shaft Propeller End Bushing & Supercharger Interm. Gear Shaft—dia. | .0005L | .004L | .013L | .102L |
| 258. | Supercharger Interm. Gear Shaft & Interm. Imp. Dr. Shaft Rear Bushing & Supercharger Rear—End Clearance | .023L | .055L | .584L | 1.397L |
| 259. | Crankshaft Rear End & Counterweight Bearing Rear—dia. | .001T | .003T | .025T | .076T |

**TABLE OF LIMITS 38 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 260. | Counterweight Rear (Crankshaft) Bearing & Counterweight Rear Bushing—dia. | .0025L | .0035L | .064L | .089L |
| 261. | Supercharger Rear Housing & Supercharger Rear Housing Sleeve—dia. | .000 | .003T | .000 | .076T |
| 262. | Crankshaft Plug & Crankshaft—dia. | .001T | .003L | .025T | .076L |
| 264. | Propeller Shaft—End Play | .0056 | .025 | .142 | .635 |
| 265.* | Starting Coupling—locating dimension | 1.714 | 1.719 | 43.536 | 43.663 |
| 266. | Gun Synch. Impulse Generator Drive Shaft—End | .0055L | .0185L | .140L | .670L |
| 266a. | Gun Synch. Impulse Gen. Drive Shaft (Bronze Gear) —End | .004L | .019L | .102L | .483L |
| 267. | Gun Synch. Impulse Generator Drive Shaft—Support and Bushings—dia. | .001T | .003T | .025T | .076T |
| 268. | Gun Synch. Impulse Generator Drive Shaft and Bushings—dia. | .001L | .004L | .025T | .102L |
| 269. | Crankshaft and Crankshaft Breather Support (Rear) —dia. | .001T | .003L | .025T | .076L |
| 270. | Crankshaft and Crankshaft Breather Support (Front)—dia. | .001L | .003L | .025L | .076L |
| 271. | Crankshaft Breather Support and Crankshaft Breather Tube—dia. | .0005L | .0025L | .013L | .064L |
| 272. | Tachometer Drive Pinion and Bushings—dia. | .001L | .005L | .025L | .127L |
| 273. | Tachometer Drive Pinion and Tachometer Drive Shaft—Backlash | .004 | .020 | .102 | .508 |
| 274. | Tachometer Drive Pinion Bushings and Housing and Housing Adapter—dia. | .001T | .003T | .025 | .076 |
| 275. | Oil Filter Bushing and Supercharger Rear Cover—dia. | .0015T | .003T | .038T | .076T |
| 276. | Oil Pump Drive Gear Spring Wire Dia. .071 in. (1.803 mm) Tension at 1.78 in. (4.521 mm) Hgt. | 8 lbs | 10 lbs | 3.63 kg | 4.54 kg |
| 277. | Cam Drive Gear & Pinion (Spline Fit) | .001T | .010L | .025T | .254L |
| 278. | Propeller Shaft Length—Thrust Nut to Center of Hole | 8.547 | 8.577 | | |
| 279. | Crankpin Plug and Crankpin—Dia. | .0005L | .002L | .013L | .05L |
| 280.* | Valve Clearance | .010 | | .25 | |

**NOTE**

If this clearance aligns oil hole in adjusting screw with split in rocker arm, turn screw in direction to increase valve clearance until hole is closed off .09 in. (2.29 mm) or until .017 in. (.43 mm) valve clearance is obtained, whichever occurs first. In no case must .017 in. (.43 mm) clearance be exceeded.

| | | | | | |
|---|---|---|---|---|---|
| 281. | Accessory Drive & Starter Shaft and Oil Retaining Plug—Dia. | .0000 | .0015T | .000 | .038T |
| 282. | Starter Coupling Spacer and Oil Retaining Plug—Dia. | .002L | .005L | .05L | .13L |

## TABLE OF LIMITS 38 Continued

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 283. | Starter Coupling Spring (Wire Diameter .125 in. Tension at .89 in. Height | 52.2 lb. | 63.8 lb. | 23.63 kg | 28.95 kg |
| 500.* | Carrier Ring to Propeller Shaft Attaching Bolt Tightening Torque | 750 in.lb | 850 in.lb | 864 cm.kg | 979 cm.kg |
| 501.* | Crankcase Front Cover Attaching Nut and Screw Also Stationary Reduction Gear Attaching Stud Nut—Tightening Torque | 300 in.lb | 350 in.lb | 346 cm.kg | 403 cm.kg |
| 502.* | Impeller Drive Shaft Gear Nut—Tightening Torque | 3750 in.lb | 4250 in.lb | 4320 cm.kg | 4896 cm.kg |
| 504.* | Reduction Gear Drive Pinion Lock Nut—Tightening Torque | 700 in.lb | 800 in.lb | 807 cm.kg | 922 cm.kg |
| 505.* | Propeller Shaft Hydro Oil Connection Cover Nut—Tightening Torque | 2000 in. lb. | 2200 in. lb. | 2300 cm kg | 2540 cm kg |

Note: Use lubriplate on threads.

## NOTES

### VALVE SPRING TENSION

| Spring | Wire dia. | Min. Load | Max. Load | |
|---|---|---|---|---|
| Inner | .135 in. (3.43 mm) | 49.5 lb (22.45 kg) | 57.75 lb (26.19 kg) | 1.438 in. (36.53 mm) |
| Inter. | .162 in. (4.11 mm) | 67.5 lb (30.62 kg) | 78.75 lb (35.72 kg) | 1.531 in. (38.89 mm) |
| Outer | .192 in. (4.88 mm) | 90.0 lb (40.82 kg) | 105.00 lb (47.63 kg) | 1.406 in. (35.71 mm) |

| | |
|---|---|
| 14 | Minimum diameter of exhaust valve stem neck—.667 (This diameter must blend in with the stem diameter at a point not less than 4 inches from the tip end of valve.) Minimum permissible diameter of exhaust valve stem—.005 in. (.127 mm) under production base figure which is .6825 in. (17.335 mm). |
| 21, 22, 23, 24, 25 | Replace piston rings at every overhaul. |
| 21a, 22a, 23a | Side clearance must be measured in four equally spaced places and is obtained when wedge ring O.D. is flush with the piston thrust faces at the skirt diameter. |
| 37 | Knuckle pins must be tight fit in master rod. |
| 61a, 79a, 108a | Select to obtain. |

**TABLE OF LIMITS 38 Continued**

| | |
|---|---|
| 86 | To be measured 1 in. from thrust bearing nut with engine hot. To secure accurate measurement an indicator must be used. |
| 98 | Bearing tight fit in master rod. |
| 149, 150 | These clearances to be maintained at all points of impeller circumference. |
| 176, 177 | Total permissible backlash in finished pump—.025 in. (0.635 mm). |
| 265 | After obtaining clearance per item No. 133, machine "spacer R" to obtain this dimension with the starter coupling located in extreme "in" position (forward against the accessory shaft resting against forward thrust ring). |
| 500, 501. 502, 504 | Threads must be lubricated with oil. |

## TABLE OF LIMITS 40

### TWO SPEED SUPERCHARGER (PLATE CLUTCH TYPE)

**(Refer to Limits Chart No. 413223)**

**For Torque Values Refer to TL-45**

**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 1. | Impeller Shaft Drive Multi Plate Clutch Gear 10:1 Ratio & Bushing—dia. | .002L | .006L | .050L | .152L |
| 2. | Interm. Imp. Driveshaft & Imp. Shaft Drive Multi-Plate Clutch Gear 10:1 Ratio—dia. | .000 | .0035L | .000 | .088L |
| 3. | Interm. Imp. Driveshaft & Piston 10:1 Ratio—dia. | .001L | .006L | .025L | .152L |
| 4. | Interm. Imp. Driveshaft & Interm. Imp. Drive Gear Bushing—dia. | .001L | .005L | .025L | .127L |
| 5. | Interm. Imp. Drive Gear & Bushing—dia. | .002T | .004T | .050T | .101T |
| 6. | Interm. Imp. Driveshaft & Sun Gear Bushing—dia. | .001L | .008L | .025L | .203L |
| 7. | Interm. Impeller Drive Sun Gear & Bushing—dia. | .002L | .008L | .050L | .203L |
| 8. | Interm. Impeller Driveshaft & Rear Bushing—dia. | .0005L | .007L | .012L | .177L |
| 9. | Interm. Imp. Driveshaft—End Play (Machine at Assembly) (Acc. Dr. Gear & Impeller Shaft Multi-Plate Clutch Gear—Side Clearance Item No. 19 is Affected by This Adjustment) | .020L | | .508L | |
| 10. | Imp. Drive Multi-Plate Clutch Piston (7.14:1 Ratio) & Interm. Imp. Dr. Shaft Rear Bushing—dia. | .0005L | .002L | .012L | .050L |
| 11. | Imp. Drive Multi-Plate Clutch Piston & Oil Seal Ring (7.14:1 Ratio)—Side Clearance | .0065L | .014L | .165L | .355L |
| 12. | Impeller Drive Multi-Plate Clutch Piston Oil Seal Ring 7.14:1 Ratio—Gap (Hand Fit) | .003 | .004 | .076 | .101 |
| 13. | Impeller Shaft Drive Multi-Plate Clutch Piston 10:1 Ratio & Oil Seal Ring—Side Clearance | .006L | .015L | .152L | .381L |
| 14. | Impeller Shaft Drive Multi-Plate Clutch Piston Oil Seal Ring 10:1 Ratio—Gap | .003 | .010 | .076 | .254 |
| 15. | Interm. Imp. Dr. Shaft Plug Check Valve Spring Wire Dia. .020 in. (0.508 mm) Tension at ½ in. (12.7 mm) Height | .22 lbs | | .099 kg | |
| 16. | Interm. Imp. Dr. Shaft Plug Check Valve & Oil Distributor Plug—dia. | .002L | .012L | .050L | .304L |
| 17. | Interm. Imp. Dr. Gear & Generator Gear—Backlash | .006 | .020 | .152 | .508 |
| 18. | Interm. Imp. Dr. Gear & Pinion & Accessory Dr. Gear—Backlash | .006 | .020 | .152 | .508 |
| 19.* | Acc. Dr. Gear & Imp. Shaft Multi-Plate Clutch Gear —Clearance | .020L | | .508L | |
| 20. | Imp. Shaft Dr. Multi-Plate Clutch Gear & Imp. Dr. Shaft Gear 10:1 Ratio—Backlash | .003 | .018 | .076 | .457 |
| 21. | Imp. Shaft Dr. Multi-Plate Clutch Gear & Imp. Dr. Multi-Plate Piston Lug—Side Clearance | .035L | .050L | .889L | 1.270L |
| 22. | Interm. Imp. Dr. Gear & Pinion & Dr. Pinion—Backlash | .004 | .015 | .101 | .381 |
| 23. | Interm. Imp. Dr. Sun Gear & Piston—Backlash | .004 | .015 | .101 | .381 |

**TABLE OF LIMITS 40 Continued**

| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 24. | Interm. Imp. Dr. Shaft & Interm. Imp. Dr. Pinion Bushing—dia. | .0015L | .007L | .038L | .177L |
| 25. | Interm. Imp. Dr. Pinion & Bushing—dia. | .0005L | .006L | .012L | .152L |
| 26. | Imp. Drive Multi-Plate Clutch Piston (7.14:1 Ratio) & Two-Speed Clutch Thrust Washer Lock—dia. | .002T | .0045T | .050T | .114T |
| 27. | Imp. Drive Multi-Plate Clutch Sleeve (7.14:1 Ratio) & Supercharger Rear Cover—dia. | .001L | .003T | .025L | .076T |
| 28. | Imp. Drive Multi-Plate Clutch Housing & Sleeve—dia. | .003L | .010L | .076L | .254L |
| 29. | Supercharger Clutch Oil Control Valve & Housing—dia. | .0005L | .0025L | .012L | .063L |
| 30. | Supercharger Clutch Oil Control Valve Housing & Supercharger Rear Cover—dia. | .0005T | .0015L | .012T | .038L |
| 31. | Supercharger Clutch Oil Control Valve Spring .47 in. (11.9 mm) O.D., .055 in. (1.39 mm) Wire Dia. Tension at 1.63 in. (41.4 mm) Height—Tension at 1.08 in (27.43 mm) Height | 4.75 lbs<br>11.40 lbs | | 2.15 kg<br>5.16 kg | |
| 32. | Imp. Clutch Release Spring (7.14:1 Ratio) Wire Dia. .093 in. (2.36 mm) Tension at ¾ in. (19.05 mm) Height | 18 lbs | | 8.16 kg | |
| 33. | Imp. Clutch Release Spring (10:1 Ratio) Wire Dia. .105 in. (2.66 mm) Tension at ½ in. (12.7 mm) Height | 16.74 lbs | | 7.59 kg | |
| 34. | Interm. Imp. Dr. Shaft Oil Distrib. Plug & Interm. Imp. Dr. Shaft—dia. | .000 | .0015T | .000 | .038T |
| 35. | Interm. Imp. Dr. Shaft Oil Distrib. Plug & Interm. Imp. Dr. Shaft—dia. | .000 | .002T | .000 | .050T |
| 36. | Interm. Imp. Dr. Pinion & Bushing—Side Clearance | .006L | .030L | .152L | .762L |
| 37. | Imp. Driveshaft Gear 10:1 Ratio—End Clearance | .005L | .014L | .127L | .355L |
| 38. | Acc. Driveshaft—Side Clearance (Machine at Assembly) | .020L | .040L | .508L | .1.016L |
| 500.* | Intermediate Impeller Drive Shaft Pipe Plug — Tightening Torque | 350 in. lb. | 400 in. lb. | 400 cm kg | 460 cm kg |

Note: Threads must be lubricated with oil.

**NOTES**

19 Adjust intermediate impeller drive shaft end play, Item No. 9, to obtain this clearance.

## TABLE OF LIMITS 45

## TIGHTENING TORQUE VALUES

**(Special cases and exceptions to TL-45 are listed in other Tables of Limits)**

**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

### Standard Studs, Bolts, Screws, and Cap Screws

| Name | Size of Thread Nut End | Min. Dia. of Thread Root or Neck (Inches) | Min. Rockwell Hardness | Torque Values | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Driving Stud | | | | Tightening Nut, Screw or Cap Screw | | | |
| | | | | Minimum | | Maximum | | Minimum | | Maximum | |
| | | | | In. Lbs. | Cm. Kg. | In. Lbs. | Cm. Kg. | In. Lbs. | Cm. Kg. | In. Lbs. | Cm. Kg. |
| Button Head Screw | 10-32 | .1467 | B-50 | — | — | — | — | 20 | 23.1 | 25 | 28.8 |
| Button Head Screw | 12-24 | .1585 | B-50 | — | — | — | — | 25 | 28.8 | 30 | 34.6 |
| Studs, Bolts, Screws and Cap Screws | 10-32 | .1467 | C-19 | — | — | — | — | 35 | 40.4 | 40 | 46.1 |
| " | 12-24 | .1585 | C-19 | — | — | — | — | 45 | 51.9 | 50 | 57.6 |
| " | 1/4-28 | .180 | C-26 | 50 | 57.6 | 70 | 80.7 | 80 | 92.3 | 85 | 98.0 |
| " | 5/16-24 | .229 | C-26 | 100 | 115.2 | 150 | 173.0 | 160 | 184.5 | 175 | 202.0 |
| " | 3/8-24 | .285 | C-26 | 200 | 231.0 | 275 | 317.0 | 225 | 259.5 | 250 | 288.0 |
| " | 7/16-20 | .331 | C-26 | 300 | 346.0 | 425 | 490.0 | 350 | 404.0 | 375 | 432.0 |
| " | 1/2-20 | .387 | C-26 | 500 | 576.0 | 700 | 807.0 | 550 | 635.0 | 600 | 692.0 |
| " | 9/16-18 | .436 | C-26 | 750 | 865.0 | 975 | 1123.0 | 825 | 950.0 | 875 | 1008.0 |
| " | 5/8-18 | .493 | C-26 | 1100 | 1269.0 | 1400 | 1614.0 | 1125 | 1297.0 | 1200 | 1383.0 |

### Standard Practices for Special Applications

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyl. Hold-Down Stud | 3/8-24 | .313 | C-32 | 325 | 375.0 | 450 | 519.0 | 350 | 404.0 | 375 | 432.0 |
| Cyl. Hold-Down Cap Screw | 7/16-20 | .330 | C-26 | — | — | — | — | 375 | 432.0 | 400 | 461.0 |
| Cyl. Hold-Down Stud | 7/16-20 | .331 | C-32 | 400 | 461.0 | 550 | 635.0 | 425 | 490.0 | 450 | 519.0 |
| Rocker Hub Bolt | 7/16-20 | .371 | C-32 | — | — | — | — | 250 | 288.0 | 325 | 375.0 |
| Rocker Hub Bolt | 15/32-20 | .400 | C-19 | — | — | — | — | 250 | 288.0 | 325 | 375.0 |
| Rocker Hub Bolt | 9/16-18 | .488 | C-26 | — | — | — | — | 300 | 346.0 | 375 | 432.0 |
| Spark Plug | 18 mm | — | — | — | — | — | — | 330 | 360.0 | 360 | 415.0 |

## TABLE OF LIMITS 75

### TORQUE INDICATOR CRANKCASE FRONT SECTION FOR .5625 (16:9) AND .666 (3:2) REDUCTION GEARED ENGINES

**(Refer to Limits Chart No. 415836)**

**For Torque Values Refer to TL-45**

**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

| Reference No. | Reference Name | Min. Inches | Max. Inches | Min. Millimeters | Max. Millimeters |
|---|---|---|---|---|---|
| 1. | Torque Ind. Booster Pump Hous. Cover & Gov. Dr. Coupling—dia. | .001L | .005L | .025L | .127L |
| 2. | Torque Ind. Booster Pump Hous. Cover & Gov. Dr. Idler Gear—dia. | .001L | .008L | .025L | .203L |
| 3. | Gov. Dr. Coupling Gear & Gov. Dr. Idler Gear—Backlash | .004 | .020 | .102 | .508 |
| 4. | Torque Ind. Booster Pump Hous. & Gov. Dr. Gear—Side Clearance | .003 | .008 | .076 | .203 |
| 5. | Torque Ind. Booster Pump Hous. & Crankcase Frt. Section—dia. | .001L | .005L | .025L | .127L |
| 6. | Gov. Drive Coupling & Booster Pump Housing—dia. | .001L | .005L | .025L | .127L |
| 7. | Torque Ind. Booster Pump Housing & Gov. Dr. Idler Gear—dia. | .001L | .008L | .025L | 203L |
| 8. | Torque Arm Support & Sleeve—dia. | .002T | .004T | .051T | .102T |
| 9. | Gov. Dr. Coupling Gear & Gov. Dr. Idler Gear & Booster Pump Hous. Cage—dia. | .004L | .010L | .102L | .254L |
| 10. | Torque Arm & Torque Ind. Overrunning Valve—dia. | .001L | .008L | .025L | .203L |
| 11. | Torque Ind. Valve Oil Seal Ring Gap | .002 | .008 | .051 | .203 |
| 12. | Torque Ind. Valve & Oil Seal Ring—Side Clearance | .002 | .010 | .051 | .254 |
| 13. | Crankcase Frt. Section & Torque Ind. Housing—Side Fit | .002T | .006L | .051T | .152L |
| 16. | Torque Arm & Stat. Red. Gear—Backlash | .002 | .010 | .051 | .254 |
| 16a. | Torque Arm & Stat. Red. Gear—Backlash | .000 | .006 | .000 | .152 |
| 17. | Torque Arm Support & Ball Thrust Bearing—dia. | .0004L | .005L | .010L | .127L |
| 18. | Torque Arm Support & Torque Arm Bearing Assy. (using exact size balls)—dia. | .001L | .004L | .025L | .102L |

## TABLE OF LIMITS 87

## TWO SPEED SUPERCHARGER (ROLLER CLUTCH TYPE)

**(Refer to Limits Chart No. 416189)**

**For Torque Values Refer to TL-45**

**All changes in the Tables of Limits are issued as Service Bulletins by the Service Division, Wright Aeronautical Corporation**

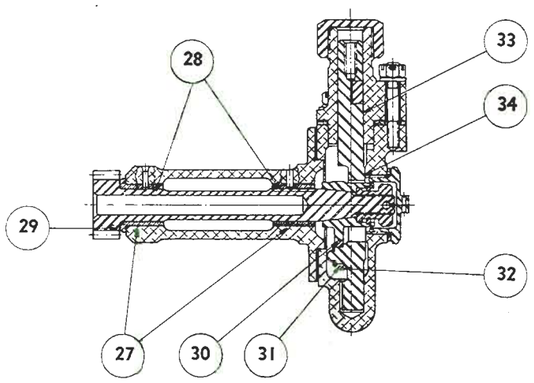
| Reference No. | Reference Name | Min. Inches | Max. Inches | Min. Millimeters | Max. Millimeters |
|---|---|---|---|---|---|
| 1. | Impeller Shaft Drive Gear & Bushing—dia. | .002L | .006L | .051L | .152L |
| 2. | Intermediate Impeller Drive Shaft & Front Bushing —dia. | .0015L | .006L | .038L | .152L |
| 3. | Impeller Shaft Drive Gear & Intermediate Drive Shaft Front Bushing—dia. | .0025T | .004T | .064T | .102T |
| 4. | Intermediate Impeller Drive Shaft & Intermediate Impeller Drive Gear Bushing—dia. | .0015L | .008L | .038L | .203L |
| 5. | Intermediate Impeller Drive Gear & Bushing—dia. | .0025T | .004T | .064T | .102T |
| 6. | Impeller Shaft Drive Gear & Intermediate Impeller Drive Pinion Cage (Front) Bushing—dia. | .0005L | .006L | .013L | .152L |
| 7. | Intermediate Impeller Drive Shaft Pinion Cage (Front) & Bushing—dia. | .0005L | .006L | .013L | .152L |
| 8. | Intermediate Impeller Drive Shaft & Rear Bushing—dia. | .0015L | .007L | .038L | .178L |
| 9. | Intermediate Impeller Drive Shaft End Play (Machine at Assembly) Item No. 39 Impeller Drive Multi-Plate Clutch Housing & Clutch Roller Cage Clearance is Affected by This Adjustment | .020L | | .508L | |
| 10. | Impeller Drive Multi-Plate Clutch Piston & Intermediate Impeller Drive Shaft Bushing (Rear)—dia. | .002L | .004L | .051L | .102L |
| 11. | Impeller Drive Multi-Plate Clutch Piston & Oil Seal Ring—Side Clearance | .0065L | .014L | .165L | .355L |
| 12. | Impeller Drive Multi-Plate Clutch Piston Oil Seal Ring (Hand Fit)—Gap | .003 | .006 | .076 | .152 |
| 13. | Clutch Roller Cage & Roller—Side Clearance | .0014L | .005L | .036L | .127L |
| 14. | Clutch Roller Cage & Roller—End Clearance | .0013L | .005L | .033L | .127L |
| 15. | Impeller Low Speed Drive Clutch Cam & Bushing—dia. | .0005T | .0025T | .013T | .064T |
| 16. | Intermediate Impeller Drive Shaft & Pinion—Backlash | .004 | .015 | .102 | .381 |
| 17. | Intermediate Impeller Drive Gear & Generator Gear —Backlash | .006 | .020 | .152 | .508 |
| 18. | Intermediate Impeller Drive Gear & Accessory Drive Gear—Backlash | .006 | .020 | .152 | .508 |
| 19. | Impeller Shaft Drive Gear & Intermediate Impeller Drive Pinion—Backlash | .006 | .017 | .152 | .432 |
| 20. | Impeller Shaft Drive Gear & Impeller Drive Shaft Gear Backlash | .003 | .015 | .076 | .381 |
| 21. | Intermediate Impeller Drive Shaft Pinion Cage (Front) & Pinion Shaft—dia. | .001L | .002L | .025L | .051L |
| 22. | Impeller Shaft Drive Gear & Intermediate Impeller Drive Pinion—Backlash | .008 | .020 | .203 | .508 |

**TABLE OF LIMITS 87 Continued**

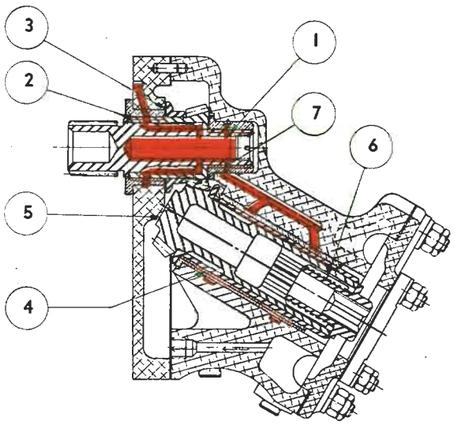
| Reference No. | Reference Name | Inches Min. | Inches Max. | Millimeters Min. | Millimeters Max. |
|---|---|---|---|---|---|
| 23. | Intermediate Impeller Drive Shaft & Pinion—Backlash | .004 | .015 | .102 | .381 |
| 24. | Intermediate Impeller Drive Shaft Pinion Cage (Front & Rear) & Pinion Bushing—dia. | .0005L | .006L | .013L | .152L |
| 25. | Intermediate Impeller Drive Pinion & Bushing (Front & Rear)—dia. | .0005L | .006L | .013L | .152L |
| 26. | Impeller Drive Multi-Plate Clutch Piston & Two-Speed Clutch Thrust Washer Lock—dia. | .002T | .0045T | .051T | .114T |
| 27. | Impeller Drive Multi-Plate Clutch Sleeve & Supercharger Rear Cover—dia. | .000 | .003T | .000 | .076T |
| 28. | Impeller Drive Multi-Plate Clutch Housing & Sleeve —dia. | .003L | .010L | .076L | .254L |
| 29. | Supercharger Clutch Oil Control Valve & Sleeve—dia. | .0005L | .0025L | .013L | .064L |
| 30. | Supercharger Clutch Oil Control Valve Sleeve & Supercharger Rear Cover—dia. | .0005T | .001L | .013T | .025L |
| 31. | Supercharger Clutch Oil Control Valve Spring—Wire Dia. .055 In.—Tension at .96 In. Height | 5 lb | | 2.27 kg | |
| 32. | Impeller Clutch Release Spring—Wire Dia. .093 In. —Tension at .75 In. Height | 18 lb | | 8.16 kg | |
| 33. | Impeller Intermediate Drive Pinion Shaft & Pinion Bushing—dia. | .0005L | .006L | .013L | .152L |
| 34. | Intermediate Impeller Drive Pinion & Bushing—dia. | .0005L | .006L | .013L | .152L |
| 35. | Intermediate Impeller Drive Shaft Pinion Cage (Rear) & Pinion Shaft—dia. | .001T | .0025T | .025T | .064T |
| 36. | Intermediate Impeller Drive Pinion & Bushing—Side Clearance | .004L | .020L | .102L | .508L |
| 37. | Impeller Drive Shaft Gear—End Clearance | .012L | .017L | .305L | .432L |
| 38. | Accessory Drive & Starter Shaft (Machine at Assembly)—End Clearance | .020L | .040L | .508L | 1.016L |
| 39. | Impeller Drive Multi-Plate Clutch Housing & Clutch Roller Cage—Clearance (Adjust Intermediate Impeller Drive Shaft End Play, Item No. 9 to Obtain This Clearance) | .030L | | .762L | |

# WRIGHT CYCLONE 9 AIRCRAFT ENGINE
## Limits and Lubrication Chart for TL-30
Dual Accessory and Gun Synchronizer Drives

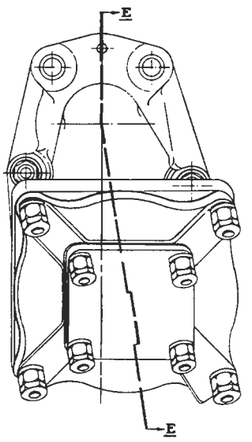
Chart No. 26 | Series C9-GC | September, 1943



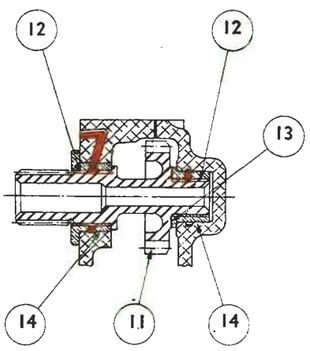
SECTION THRU
GUN SYNCHRONIZER



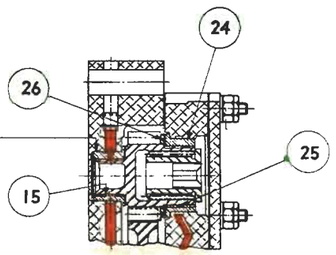
SECTION E - E



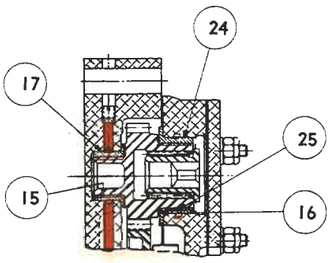
ANGLE ACCESSORY DRIVE



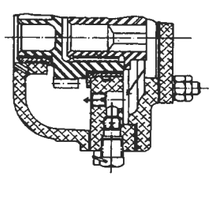
SECTION B - B

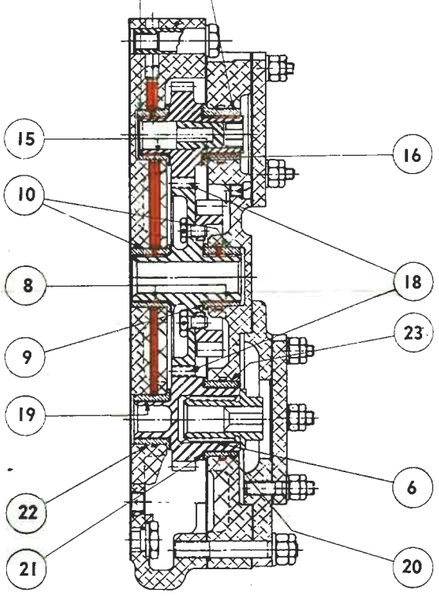


SECTION THRU UPPER VACUUM PUMP DRIVE
COUPLING HAVING INVOLUTE SPLINE
(SPECIAL)

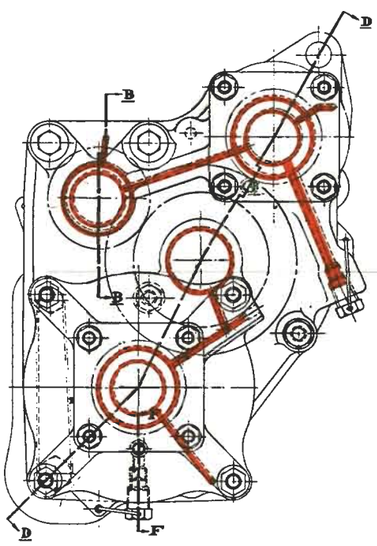


SECTION THRU UPPER VACUUM PUMP DRIVE
COUPLING HAVING INVOLUTE SPLINE
(STANDARD)


SECTION F-F



SECTION D - D



DUAL ACCESSORY DRIVE

NUMBERS REFER TO THE SERVICE CLEARANCES
LISTED IN TABLE OF LIMITS NO. TL - 30
PRESSURE SYSTEM  SCAVENGE SYSTEM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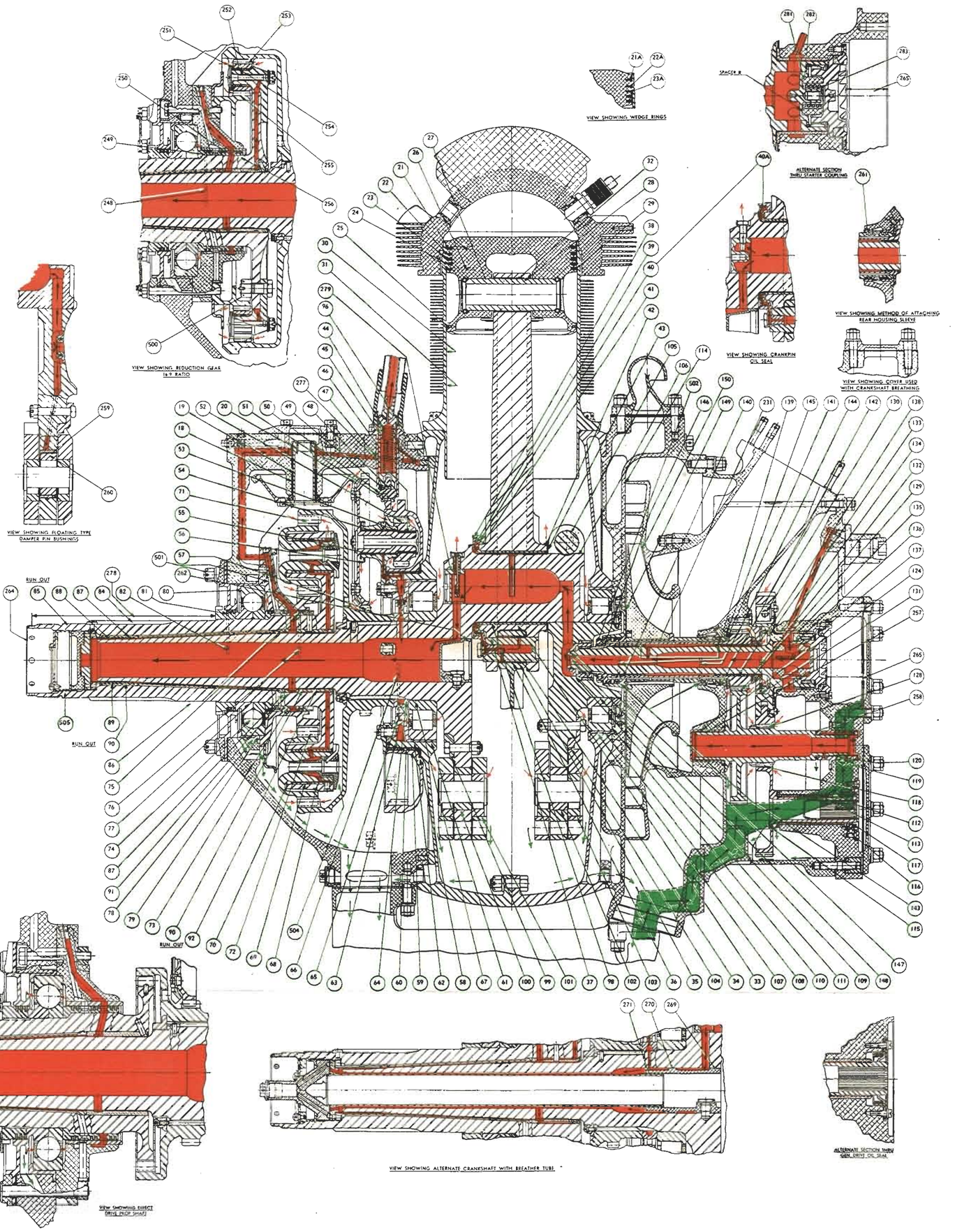
# WRIGHT CYCLONE 9 AIRCRAFT ENGINE
## Limits and Lubrication Chart for TL-38

Longitudinal Section

Chart No. 28 — Series C9-GC — September, 1943


VIEW SHOWING REDUCTION GEAR 16:9 RATIO
VIEW SHOWING WEDGE RINGS
ALTERNATE SECTION THRU STARTER COUPLING
VIEW SHOWING METHOD OF ATTACHING REAR HOUSING SLEEVE
VIEW SHOWING CRANKPIN OIL SEAL
VIEW SHOWING COVER USED WITH CRANKSHAFT BREATHING
VIEW SHOWING FLOATING TYPE DAMPER PIN BUSHINGS
RUN OUT
RUN OUT
RUN OUT
VIEW SHOWING ALTERNATE CRANKSHAFT WITH BREATHER TUBE
ALTERNATE SECTION THRU GEAR DRIVE OIL SEAL
VIEW SHOWING INJECT DRIVE SHAFT

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. TL-38

PRESSURE SYSTEM — SCAVENGE SYSTEM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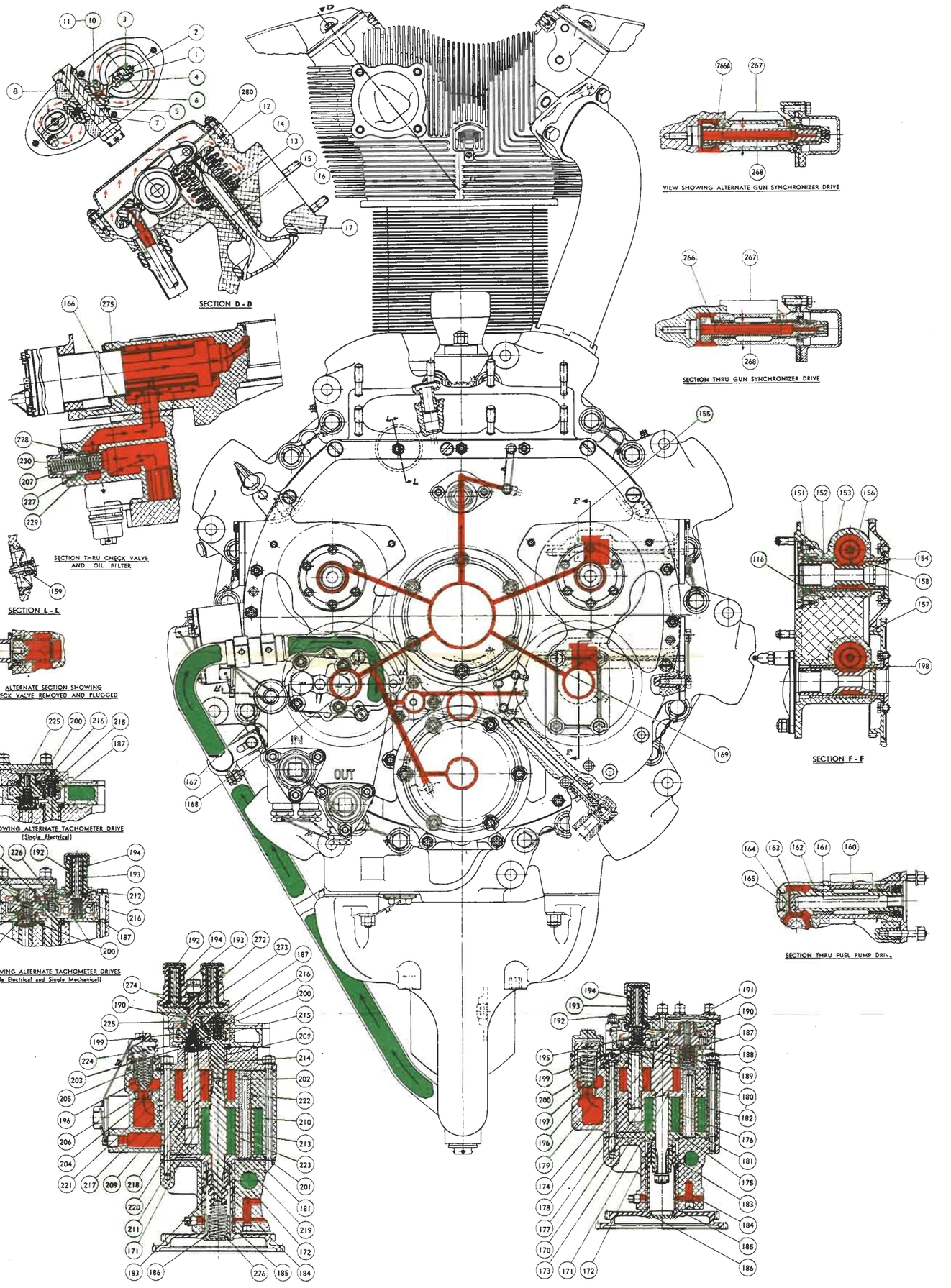
# WRIGHT CYCLONE 9 AIRCRAFT ENGINE
## Limits and Lubrication Chart for TL-38

Section Through Accessory Drives

Chart No. 29 — Series C9-GC — September, 1943


SECTION D - D
VIEW SHOWING ALTERNATE GUN SYNCHRONIZER DRIVE
SECTION THRU GUN SYNCHRONIZER DRIVE
SECTION THRU CHECK VALVE AND OIL FILTER
SECTION L - L
ALTERNATE SECTION SHOWING CHECK VALVE REMOVED AND PLUGGED
SECTION F - F
VIEW SHOWING ALTERNATE TACHOMETER DRIVE (Single Electrical)
VIEW SHOWING ALTERNATE TACHOMETER DRIVES (Single Electrical and Single Mechanical)
SECTION THRU FUEL PUMP DRIVE
SECTION H - H
VIEW SHOWING ALTERNATE OIL PUMP
OUT

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. TL - 38

PRESSURE SYSTEM  SCAVENGE SYSTEM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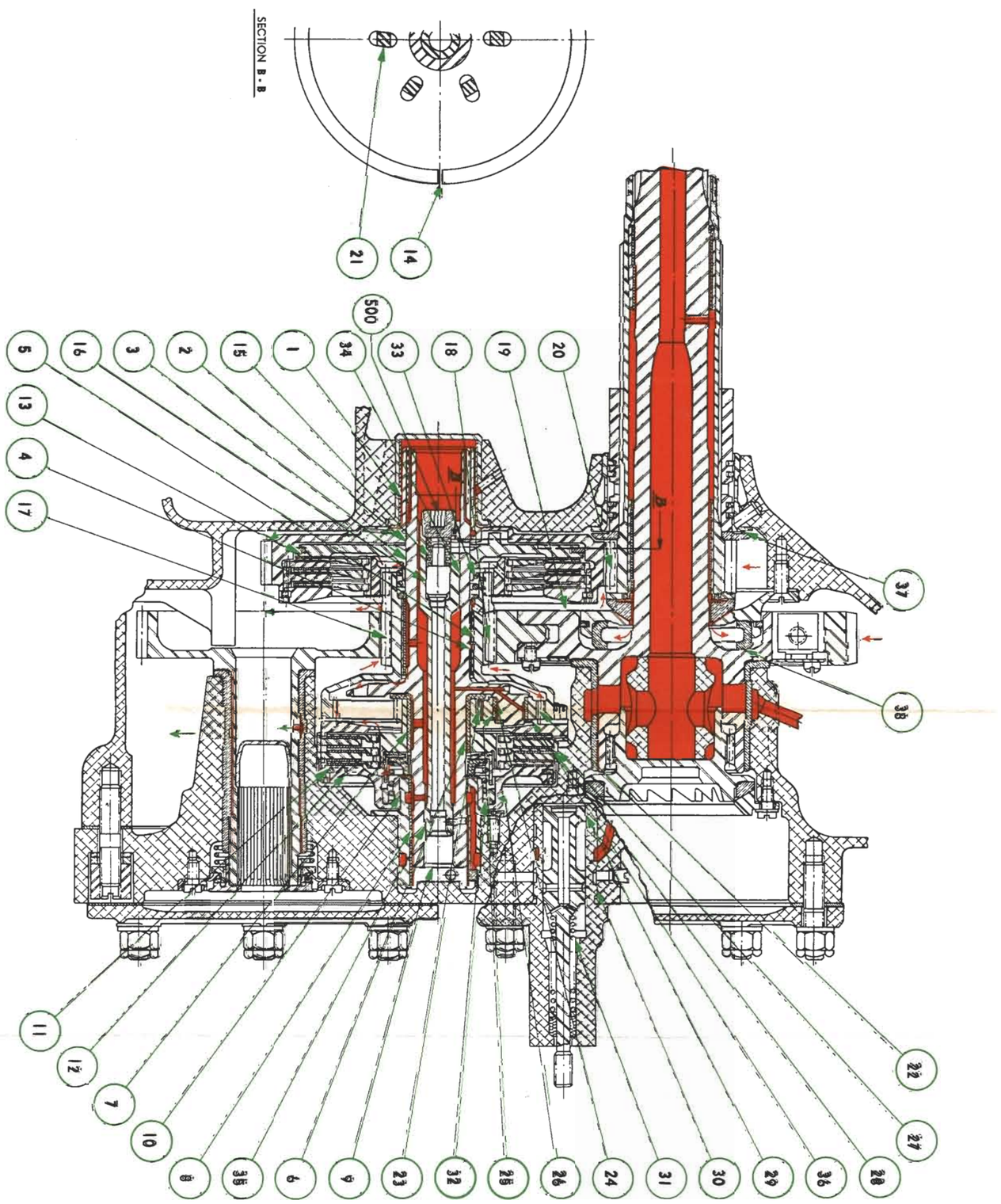
# WRIGHT CYCLONE 9 AIRCRAFT ENGINE

## Limits and Lubrication Chart for TL-40

Two Speed Supercharger (Plate Clutch Type)

Series C9-GC

September, 1943




NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. TL - 40

PRESSURE SYSTEM SCAVENGE SYSTEM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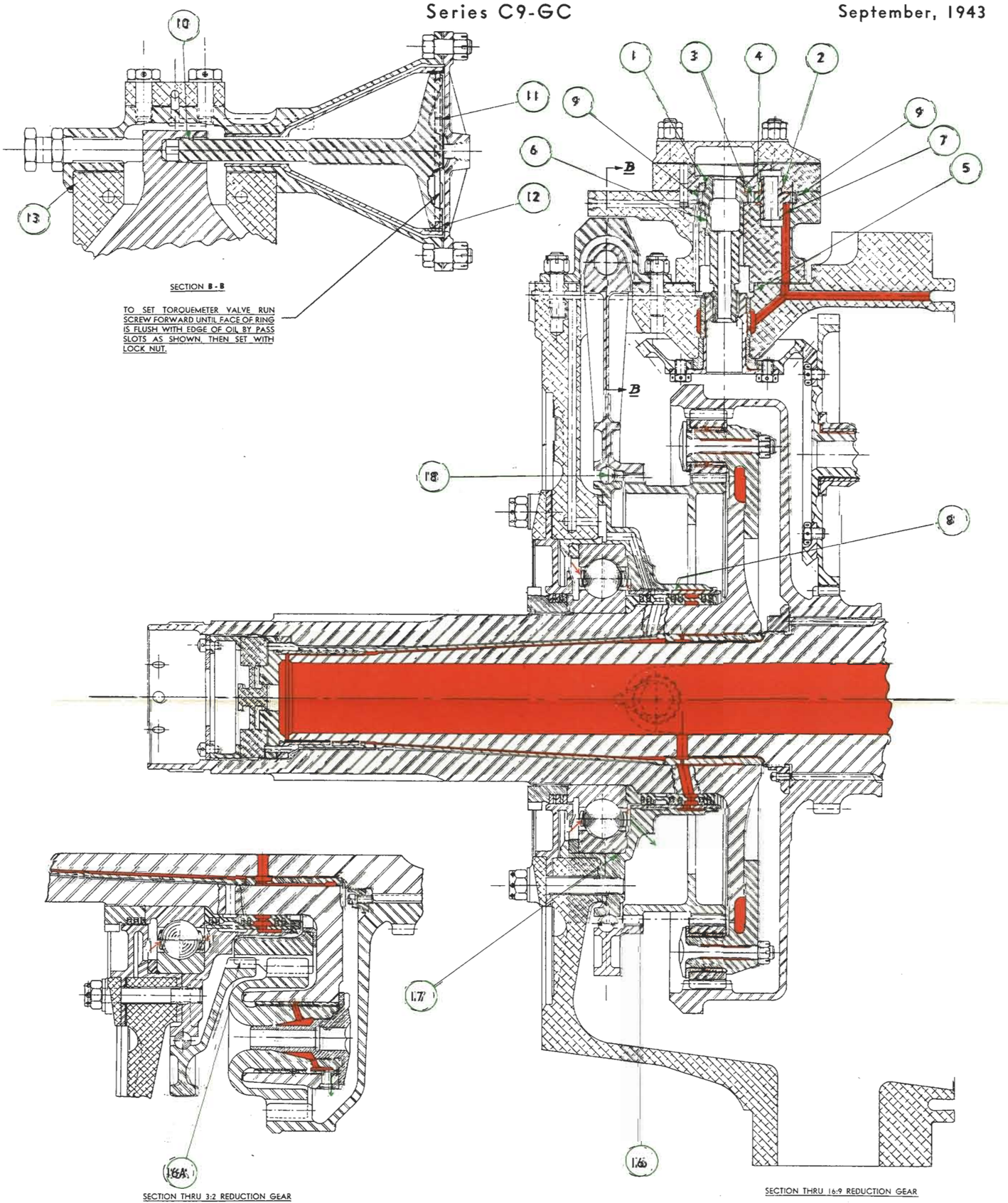
# WRIGHT CYCLONE 9 AIRCRAFT ENGINE

## Limits and Lubrication Chart for TL-75

Torquemeter

Series C9-GC

September, 1943




NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. TL-75

PRESSURE SYSTEM SCAVENGE SYSTEM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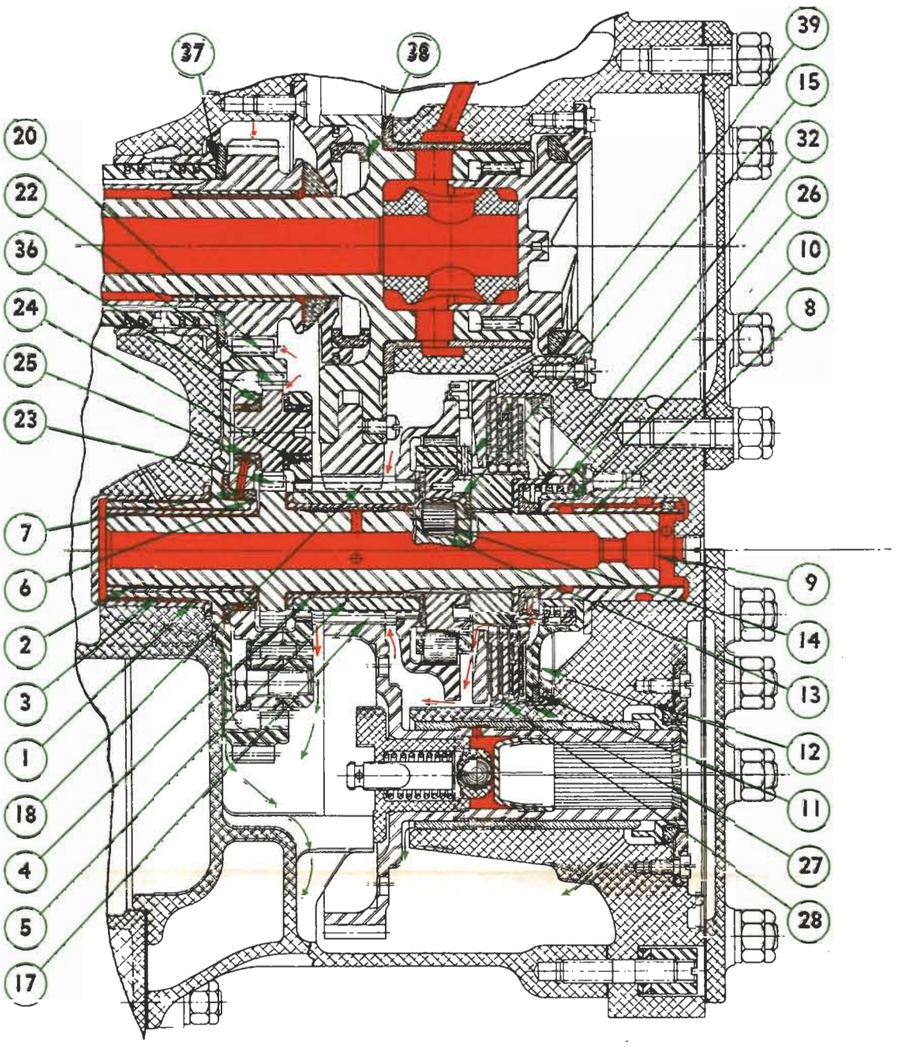
# WRIGHT CYCLONE 9 AIRCRAFT ENGINE

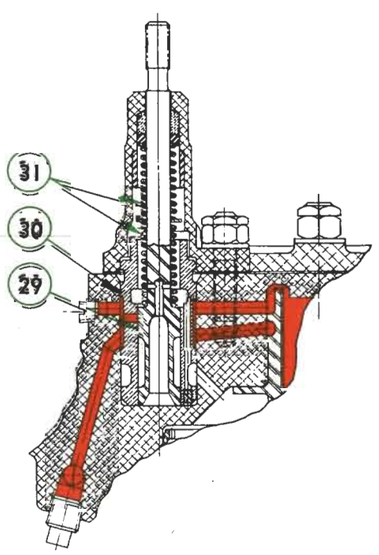
## Limits and Lubrication Chart for TL-87

Two-Speed Supercharger (Roller Clutch Type)

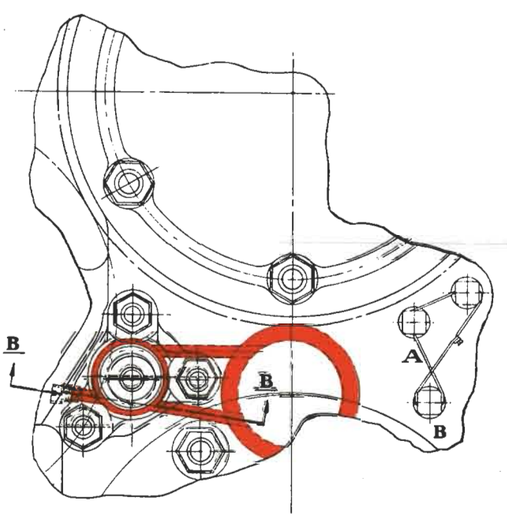
Chart No. 30 | Series C9-GC | September, 1943




7.134:1 & 10.04:1 RATIOS




SECTION B - B




VIEW SHOWING
SUPERCHARGER CLUTCH OIL CONTROL VALVE

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. TL-87

PRESSURE SYSTEM SCAVENGE SYSTEM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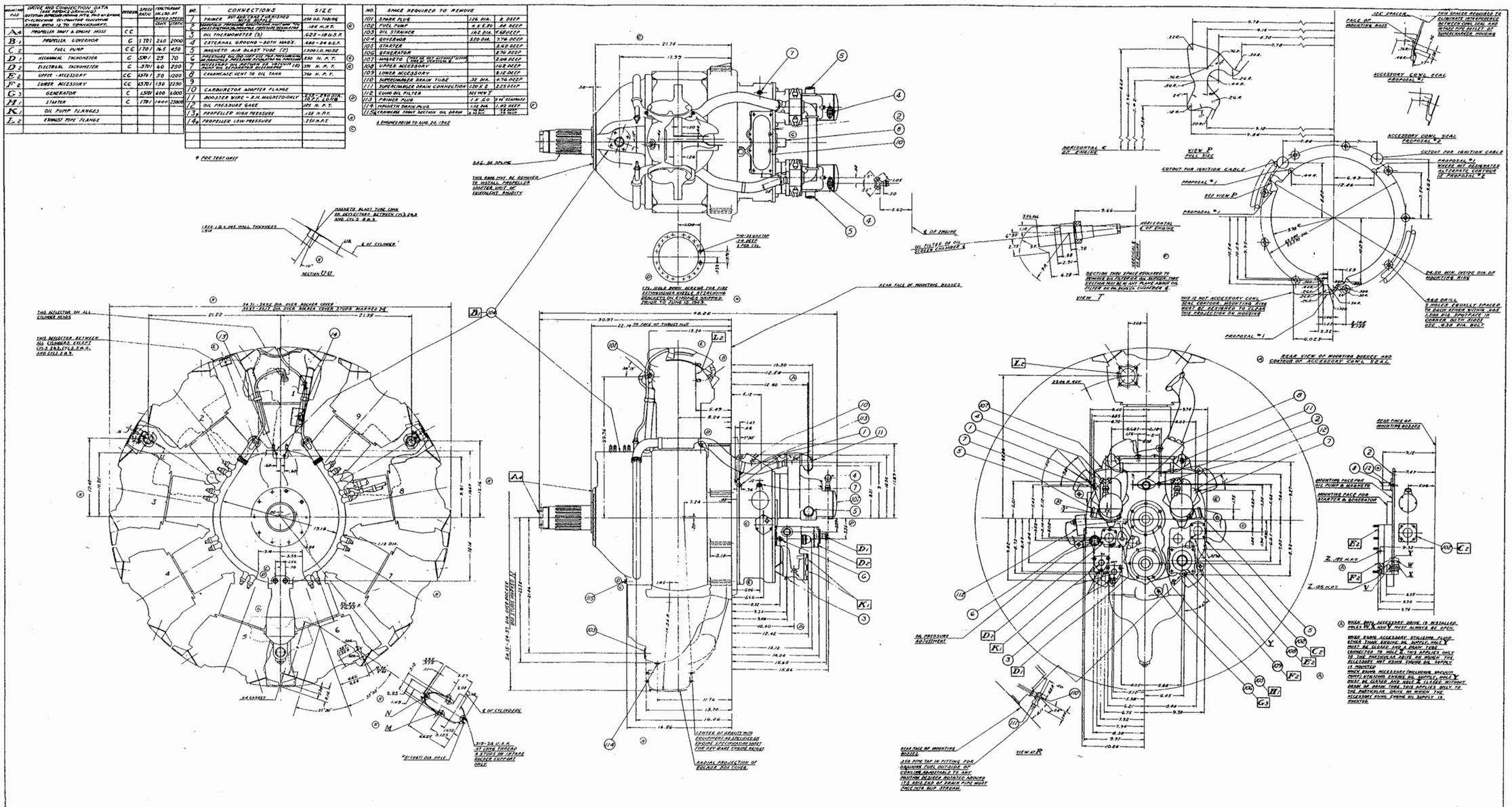
| DRAWING PAD | DRIVE AND CONNECTION DATA (SEE REFERENCE DRAWING) (LETTERS REFERRED FROM PTS. PAD NUMBER. CYLINDRICAL OR TAPERED CONNECTIONS SHARE BOTH 'A' TO CENTERLINE) | DIRECTION | SPEED RATIO | TORQUE IN LBS. AT RATED SPEED | |
|---|---|---|---|---|---|
| | | | | CONT | STATIC |
| $A_3$ | PROPELLER SHAFT & ENGINE NOSE | CC | | | |
| $B_1$ | PROPELLER GOVERNOR | G | 1.701 | 260 | 2000 |
| $C_2$ | FUEL PUMP | CC | 1.701 | N-S | 450 |
| $D_1$ | MECHANICAL TACHOMETER | C | .5701 | 25 | 70 |
| $D_2$ | ELECTRICAL TACHOMETER | C | .5701 | 60 | 250 |
| $E_2$ | UPPER - ACCESSORY | CC | .4376 | 170 | 1200 |
| $F_2$ | LOWER ACCESSORY | CC | .4376 | 130 | 1230 |
| $G_3$ | GENERATOR | C | .4376 | 600 | 6000 |
| $H_1$ | STARTER | C | .1781 | 1400 | 2300 |
| $K_1$ | OIL PUMP FLANGES | | | | |
| $L_2$ | EXHAUST PIPE FLANGE | | | | |

| NO. | CONNECTIONS | SIZE | |
|---|---|---|---|
| 1 | PRIMER "AT CYLINDER TUBE INSTALLED WITH NOZZLE" | .258 O.D. TUBING | |
| 2 | MAGNETO CRANKCASE BREATHER TUBE (ONE MAG. ONLY) (RESTRICTION TO PREVENT OIL LEAKAGE REQUIRED) | .125 N.P.T. | |
| 3 | OIL THERMOMETER (S) | .625-18 U.S.F. | |
| 4 | EXTERNAL GROUND - BOTH MAGS. | #10-24 U.S.F. | |
| 5 | MAGNETO AIR BLAST TUBE (2) | 1.500 I.D. HOSE | |
| 6 | ACCESSORY OIL SECTION TO TACHOMETER (4) (MACHINED ON SECTION TO TACHOMETER) | .250 N.P.T. | |
| 7 | ACCESSORY OIL SECTION TO BREATHER (4) (MACHINED ON SECTION TO BREATHER) | .375 N.P.T. | |
| 8 | CRANKCASE VENT TO OIL TANK | .750 N.P.T. | |
| 9 | | | |
| 10 | CARBURETOR ADAPTER FLANGE | | |
| 11 | BOOSTER WIRE - R.H. MAGNETO ONLY | .125 - .250 DIA. (0.D.) x .625 LG. | |
| 12 | OIL PRESSURE GAGE | .125 N.P.T. | |
| $13_A$ | PROPELLER HIGH PRESSURE | .132 N.P.T. | |
| $14_A$ | PROPELLER LOW PRESSURE | .250 N.P.T. | |

* FOR TEST ONLY

| NO. | SPACE REQUIRED TO REMOVE | | |
|---|---|---|---|
| 101 | SPARK PLUG | .126 DIA. | .8 DEEP |
| 102 | FUEL PUMP | 4.9 E.D. | .46 DEEP |
| 103 | OIL STRAINER | .162 DIA. | .9 DEEP |
| 104 | GOVERNOR | .510 DIA. | 1.76 DEEP |
| 105 | STARTER | | 2.62 DEEP |
| 106 | GENERATOR | | 2.76 DEEP |
| 107 | MAGNETO (ONLY IN DIRECTION OF ROTATION) | | 2.06 DEEP |
| 108 | UPPER ACCESSORY | | 1.62 DEEP |
| 109 | LOWER ACCESSORY | | 1.12 DEEP |
| 110 | SUPERCHARGER DRAIN TUBE | .32 DIA. | 4.76 DEEP |
| 111 | SUPERCHARGER DRAIN CONNECTION | 1.20 X .2 | 2.25 DEEP |
| 112 | CLEAN OIL FILTER | SEE VIEW T | |
| 113 | PRIMER PLUG | 1 X .50 | 1.90 CLEARED |
| 114 | MAGNETIC DRAIN PLUG | 1.32 DIA. | 1.00 DEEP |
| 115 | CRANKCASE FRONT SECTION OIL DRAIN | 2.50 DIA. | 1.5 DEEP |

6 ENGINES PRIOR TO AUG. 20, 1942


SEE VIEW P
SEE VIEW T
SECTION THRU SPACE REQUIRED TO REMOVE OIL FILTER OR OIL SUCTION TUBE (SECTION MAY BE IN ANY PLANE ABOUT OIL FILTER OR OIL SUCTION CHAMBER)
VIEW P
FULL SIZE
VIEW T
ACCESSORY COWL SEAL PROPOSAL "B"
ACCESSORY COWL SEAL PROPOSAL "A"
ACCESSORY COWL SEAL PROPOSAL "C"
CUTOUT FOR IGNITION CABLE
PROPOSAL "A"
PROPOSAL "B"
PROPOSAL "C"
SEE VIEW P
HORIZONTAL ℄ OF ENGINE
℄ OF ENGINE
OIL FILTER OR OIL SCREEN CHAMBER
SPACE FOR MOUNTING BOSSES
REAR FACE OF MOUNTING BOSSES
REAR VIEW OF MOUNTING BOSSES AND CONTOUR OF ACCESSORY COWL SEAL
MAGNETO BLAST TUBE COWL TO BE DECALETTED BETWEEN CYL'S 2 & 3 AND CYL'S 8 & 9
SECTION "F-F"
THIS DEFLECTOR ON ALL CYLINDER HEADS
THIS DEFLECTOR BETWEEN ALL CYLINDERS EXCEPT CYLS 2 & 3, CYLS 5 & 6, AND CYLS 8 & 9
.04 GASKET
℄ OF CYLINDERS
.312-24 U.S.S. "T" LONG THREAD
STUDS OR INTAKE ROCKER SUPPORT ONLY
"E" (.0937 DIA. HOLE)
CENTER OF GRAVITY FOR EQUIPMENT AS SPECIFIED ON ENGINE SPECIFICATIONS SAVE FOR PROPELLER REDUCTION GEAR
RADIAL PROJECTION OF ROCKER BOX COVER
OIL PRESSURE ADJUSTMENT
REAR FACE OF MOUNTING BOSSES
.250 DIA. TAP IN FITTING FOR DRAINING FUEL OUTSIDE OF COWLING IS ADJUSTABLE TO ANY POSITION DESIRED. ROTATED AROUND ITS AXIS. END OF DRAIN PIPE MUST PROTRUDE SLIP STREAM.
VIEW AT R
MOUNTING FACE FOR OIL PUMP & MAGNETO
MOUNTING FACE FOR STARTER & GENERATOR
Z .125 M.P.V.
Z .125 M.P.V.
WHEN ENGINE ACCESSORY SYSTEM IS OF WRIGHT TYPE, EXCEPT OIL SUPPLY, HOLE M MUST BE CLOSED AND A DRAIN TUBE CONNECTED TO HOLE N. THIS APPLIES ONLY TO THE PARTICULAR POINT OF WHICH THE ACCESSORY MFT. DRAWS ENGINE OIL SUPPLY IS PROVIDED.
WHEN ENGINE ACCESSORY (INCLUDING VARIABLE PUMP) WITH ENGINE OIL SUPPLY, HOLE M MUST BE CLOSED AND HOLE N CLOSED WITHOUT DRAIN OR DRAIN TUBE. THIS APPLIES ONLY TO THE PARTICULAR DRIVE ON WHICH THE ACCESSORY DRAWS ENGINE OIL SUPPLY IS MAINTAIN.

# WRIGHT AIRCRAFT ENGINES CYCLONE 9GC

Drawing No. 414820

COVER PLATES ARE SUPPLIED ON ALL ACCESSORY DRIVES AND PLUGS IN ALL TAPPED HOLES.
FOR ADDITIONAL DATA ON SUBJECTS DESIGNATED BY LETTER SEE DRAWING 415155

WRIGHT AIRCRAFT ENGINES
CYCLONE 9GC
Drawing No. 415155

FOR PICTURE, DIMENSIONS, AND NOTES NOT SHOWN SEE SYMBOLIC INSTALLATION DRAWING.

B-1

C-1

C-2

D-1

D-2

E-1

E-2

F-1

F-2

A-1

A-2

A-3

A-4

G-1

G-2

G-3

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L-1

L-2

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